

Dear Prof. Dr. Dodd,

Thank you for the opportunity to submit revisions for our manuscript.

We thank the reviewers for their comments and are uploading a revised version of the manuscript. In the following, we are addressing the reviewers' comments in detail.

Sincerely,

Björn Jörges

# Response to the reviewers:

## Reviewer: 1

### Comments to the Author

The authors propose a study into the perception of object speed during real and simulated lateral self-motion. The idea is well motivated, the hypotheses well reasoned, and the study well designed (note that I am no expert on power analysis, but their logic in that section seems entirely reasonable). My comments are very minor only:

Some references that the authors should consider including:

- MacNeilage, P. R., Zhang, Z., DeAngelis, G. C., Angelaki, D. E. (2012) Vestibular facilitation of optic flow parsing. PLoS One 7: e40264, doi:10.1371/journal.pone.0040264. had a sideways motion condition
- Niehorster, D.C., Li, L. (2017) Accuracy and Tuning of Flow Parsing for Visual Perception of Object Motion During Self-Motion. I-Perception 8(3). Doi: 10.1177/2041669517708206 accuracy of visual-only flow parsing
- Warren, P. A., Rushton, S. K. (2007) Perception of object trajectory: Parsing retinal motion into self and object movement components. Journal of Vision 7: 2.1–11. doi:10.1167/7.11.2: has a sideways motion condition
- Rushton, S. K., Warren, P. A. (2005) Moving observers, relative retinal motion and the detection of object movement. Current Biology 15: R542–R543. doi:10.1016/j.cub.2005.07.020. original statement of flow parsing hypothesis

- 1.1 Thank you for drawing our attention to these. We have now added reference to these studies and their discussed their similarities with and differences to our experiment.

**Significance statement is not convincing: the tasks mentioned (collision avoidance, timing interaction with world) may well be done based on egocentric cues, without flow parsing**

- 1.2 Humans recover, represent and use allocentric information (e.g., about the physical speed of an object) in many instances, not exclusively, but more so when egocentric information is unreliable (due to noise), not available in a timely fashion (neural delays), or not available at all (occlusions). In the cases we mentioned, we might partially rely on a representation of the physical velocity of a car we are trying to overtake to decide when we can switch back to our previous lane, when the depth information available in the mirror is very noisy. When hitting back a tennis ball, neural delays would lead us to miss the ball if we weren't able to predict its path. Such judgements depend on a representation of its physical direction and velocity in an allocentric world frame. The task used in the present experiments requires judgements not of egocentric motion (which would be unaffected by self-motion) but of object motion relative to the world. We have edited the significance statement accordingly.

**Sentence two of introduction, “vice versa” is vague, be explicit about the second case**

1.3 Rewritten

**“an accurate estimate of the object velocity” remove “the” or make object possessive**

1.4 Addressed

**First line of page two, please rewrite, unclear what “simulation” means**

1.5 We added “retinal”, but we think the reviewer might have misread “stimulation” for “simulation”.

**Participants section: I assume you mean to say that you do NOT believe your results would be likely...**

1.6 Yes! Thank you

## **Reviewer: 2**

### **Comments to the Author**

**This registered report describes experiments to test the flow parsing hypothesis specifically for lateral visually-simulated self-motion. Specifically, results will evaluate the hypotheses that 1) accuracy in judgement of object motion is affected, i.e. judgements are biased due to incomplete compensation for self-motion, 2) precision of judgement of object motion is affected, with decreased precision during self-motion because of added noise on the self-motion estimate. The study is most similar to Dokka et al (2015) who performed similar experiments but with the object moving vertically rather than horizontally.**

**The following observations should be addressed for this report to be considered:**

**1) The study aims to replicate only 1 condition (visual-only) out of the many that were conducted by Dokka et al (2015)**

2.1 We added a paragraph to detail in what ways our study adds to the literature. We introduce two novel elements: an immersive 3D environment and psychophysical probing velocity rather than direction as a proxy of velocity. This is not a replication of Dokka et al. 2015 who did not assess perceived speed although it will be relevant to discuss how our data compare with theirs in the discussion.

**2) While authors note differences between the previous study and their own and**

**suggest that they expect to see smaller effects due to differences, the reason for these expectations are not laid out in detail. Detailed description of difference between the proposed study and the previous study must be laid out to justify the need for the registered report.**

2.2 We added more detail about differences in the introduction and in the relevant section in the power analysis.

**3) Generally, more detail is needed concerning the methods. For example, the only visual feature that can be used to judge self-motion is the background wall, but the visual features of this wall are not described.**

2.3 Thank you for this comment. We added a verbal description, a screenshot from the experiment and a link to a video of the experimental display.

**4) There is a concern that the study is not measuring flow parsing, but instead may be measuring induced motion, i.e. change in perception of motion of a central object due to surround motion.**

2.4 Induced motion is when the background moves (e.g., drifting clouds) and makes objects in front of it (e.g., the moon) appear to be moving in the opposite direction. So here, when the person is simulated as moving to the left, the background moves to the right and this could induce ball motion to the left (by induced motion). That is, it might increase its perceived speed if the ball actually were moving to the left (same direction as the simulated motion) or decrease it if it were moving to the right (opposite to the simulated motion). Our hypothesis in this situation is the opposite as we expect that self-motion would be underestimated and that when the ball moves in the same direction as the simulated motion its motion would be underestimated because of the cancelling effect of the self-motion on its retinal motion and inadequate compensation. Therefore, if we find an effect in the predicted direction, this represents even stronger evidence in favor of our hypothesis.

**5) Use of the past tense in the methods section suggests that experiments may already be underway, but APP specifically requires that data collection only begin after approval of the registered report.**

2.5 Data collection has not started yet. APP requires the Stage 1 RR to be written in past tense, as if data collection had already happened.

**Detailed comments:**

**Page 1 / line 27: “self-motion is likely to be underestimated”Because self-motion is visually simulated, one must specify the reference, relative to simulated self-motion or relative to**

**the actual self-motion, which is zero. In general, do the authors suggest that flow parsing only happens when self-motion is perceived, i.e. duringvection, or can flow parsing be probed even in the absence of perceived self-motion?**

2.6 Thank you for pointing out this possibility. As all of our pilot subjects reported that they perceived themselves as moving, we had not considered that some participants might not experience self-motion. As we see it, there are three scenarios:

- (a) The participant perceives self-motion.
- (b) The participant has the impression that they are static and the world is moving, and they judge motion relative to themselves. In this case, we'd expect full the self-motion velocity added on top of the object velocity. This could be regarded as a failure to take self-motion into account when judging object velocity.
- (c) The participant has the impression that they are static and the world is moving, and they judge motion relative to the world. In this case, our task would measure how well participants estimate the relative speed of two objects moving in the world. This is not the question this project aims to answer.

We are of course mainly interested in Scenario 1 and to a minor extent Scenario 2. Scenario 3 would not be relevant to our research question. We will therefore ask our participants after finishing the task if they had perceived the world or themselves as moving. We will continue data collection until we tested 16 participants who reported that they were moving themselves. If several subjects don't perceive themselves to move, we will conduct exploratory analyses between both groups. We added a paragraph to the participants section to elaborate on this issue.

**1/40: "while moving themselves" but the subjects are never physically moving**

2.7 Clarified by referring to "visual evoked self-motion" instead.

**1/52: "accurate estimate of the object velocity" but only if the judgment needs to be made in world coordinates. For many behavior tasks, it is sufficient to judge how the object is moving relative to the observer, in which case no flow parsing is needed.**

2.8 We added a paragraph detailing the circumstances under which flow parsing is needed and limited the scope of our significance statement accordingly. While we acknowledge the merit of ecological approaches, we believe that our study provides important insights for tasks that are better solved in an allocentric reference frame. Furthermore, many computational approaches and models of human behavior are based on the assumption that humans recover and represent physical properties of their environment.

**1/55: note ambiguous retinal input is unusual in natural circumstances due to the visible background**

- 2.9 We were referring to the ambiguity that, if the observer doesn't know how fast they are moving, they also don't know which fraction of the retinal stimulation is due to their own movement and which fraction is due to object motion. This is, in our understanding, independent of the visibility of the background although the motion of the background makes the assessment of self-motion easier. We adjusted the wording in the manuscript to avoid ambiguities.

**2/6: “underestimated” that is if vection is induced in the first place**

- 2.10 Agreed; see above.

**2/22: “caused by the observers motion” as a function of depth**

- 2.11 Added

**2/30: “insufficient flow parsing” or insufficient compensation for self-motion. These have distinct meanings.**

- 2.12 We adjusted the wording to “compensation” to reflect the paper we are describing there.

**3/7: “tested” or will test?**

2. 13 See above; APP requires past tense

**3/21: It is strange to talk about self-motion when observers remain stationary at all times**

2. 14 We went through the document and made it clearer that participants were moved visually only.

**3/26: It may be useful to know what the eyes are doing, e.g. via eye tracking**

2. 15 This would be an interesting question. We are aware and agree that eye-movements can influence perception: for example, the Fleischl-Aubert phenomenon could lead participants to perceive a single target to be moving as slower than it really is. However, this effect should apply equally to all conditions and should thus be cancelled out when we compare them. It would only be a concern if the perception of visual self-motion was somehow mediated by eye-movements. While we can't rule this out completely, we believe that

asking subjects to keep their eyes on the fixation cross will minimize this issue and any impact will be negligible.

We also realized that we had not mentioned the fixation cross in the method section and added this information.

**3/34: The starting position of the ball is not specified**

2.16 Added.

**4/50: Proposed analysis methods appear appropriate.**

2.17 Thanks.

**7/20: “we recruited” instead of “will recruit”**

2.18 See above, APP requires past tense for Registered Reports.