# Do Humans Maintain a Representation of the Air Drag in their environment?

The importance of ecologically valid stimuli for the study of interceptive actions is self-evident. Nonetheless, many studies neglect air drag when simulating stimuli in virtual reality. While this can facilitate some aspects of setup and analysis, it may lead to systematic errors in results. There is evidence that humans represent and use different physical properties of their environment, such as the size of known objects (Hosking & Crassini, 2010; López-Moliner, Field, & Wann, 2007), their mass (Neupärtl, Tatai, & Rothkopf, 2020) or gravity (Bosco et al., 2015; Gómez & López-Moliner, 2013; Indovina et al., 2005; B. Jörges & López-Moliner, 2019; Björn Jörges & López-Moliner, 2017, 2020; La Scaleia, Zago, Moscatelli, Lacquaniti, & Viviani, 2014; Lacquaniti et al., 2013; J McIntyre, Zago, & Berthoz, 2001; Joseph McIntyre, Zago, Berthoz, & Lacquaniti, 2003; Mijatovic, La Scaleia, Mercuri, Lacquaniti, & Zago, 2014; Senot, Zago, Lacquaniti, & McIntyre, 2005; Senot et al., 2012; Zago, La Scaleia, Miller, & Lacquaniti, 2011), in their interactions with the environment. The present study aims to investigate whether air drag is among these physical properties represented by the brain. We furthermore ask to what extend previous experience with objects plays a role for leveraging a possible internal model of earth drag, in comparison to online information available through observation of the stimulus.

Offline solutions have been proposed to this problem (d’Avella, Cesqui, Portone, & Lacquaniti, 2011).

We present participants with parabolic trajectories in the fronto-parallel plane in a rich 3D environment that provides cues about the distance to the target, at a simulated distance of about 6m from the participant. The ball disappears after reaching peak and participants indicate by button press when the ball drops back to the height it was launched from (indicated by a simulated table). Then, the ball reappears in a random position drawn from a uniform distribution around the simulated point-of-impact and participants use a joystick to move the ball, indicating the position where they thought the ball hit the table.

Both timing and spatial responses will be centered around the expected values of motion occurring under the assumption of air drag, independently of whether motion under air drag is presented or not. That is, the accuracy will be higher for trials where air drag is simulated, and lower for trials where no air drag is simulated. More concretely:

Hypothesis 1a) – the temporal errors for trials where air drag is simulated should be centered around zero, while responses should occur slightly too late with respect to the simulated time-of-impact for no-air-drag;

Hypothesis 1b) – the spatial errors for air drag trials should be centered around zero, while there should be an undershoot (response too far to the left in our setup) for no air drag trials

In the case that only one of the two hypotheses is supported by the evidence, we give more weight to hypothesis 1b) as differences are more pronounced, giving it a higher power (see power analysis). We furthermore adjust the alpha for both hypotheses through a bonferroni correction, as we use two hypothesis to test for the same result.

If we find an effect of air drag, we further compare trials where the texture of the target is congruent with its air drag relevant properties (e.g. a target of tennis ball texture, size and mass) with trials where they are incongruent (e.g. a target of tennis ball texture, but basket ball size and mass).

We expect increased accuracy for congruent trials. Our power analysis reveals that the effect is too small to be reasonably detectable in the temporal domain. For this reason, we rely only on the spatial domain for this hypothesis:

Hypothesis 2) – For congruent trials with airdrag, the absolute mean spatial error will be lower than for incongruent trials.

Any further analysis will be marked as exploratory.