Excuse me! Perception of Abrupt Direction Changes Using Body Cues and Paths on Mixed Reality Avatars

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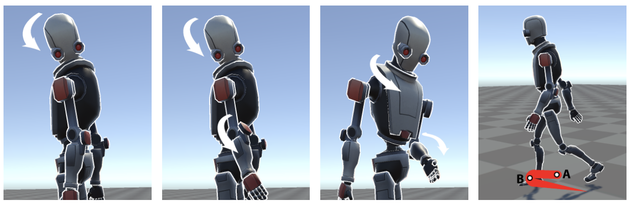

(a) Body low **(b) Body medium** **(c) Body high** **(d) Path low**

Figure 1: Expressivity levels.

ABSTRACT

We evaluate abrupt turn signalling using Mixed Reality avatars with two methods: A method where the avatar signals using its body, and a method where a path is rendered on the floor. Results indicate that study participants prefer the body method but that the path method is more accurate when the path is longer.

KEYWORDS

Robot, Interaction, Perception, Intentions, Externalizing, AR, VR

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1 INTRODUCTION

Imparting social characteristics and predictability to robots is typically approached by humanoid builds, by adapting gestures and gaze [2, 3], or by adapting locomotion to be more expressive and predictable [1]. All of these approaches however, impose constraints on the design of the robot or its locomotion method. i.e. If the robot must perform expressive movements to cater for bystanders, then it cannot travel to its next waypoint using the shortest trajectory possible, or with the most energy efficient locomotion method.

We specifically examine abrupt direction changes because they are a potential cause of discomfort to bystanders: When humans make significant changes in walking direction they convey this change with a number of body cues including gaze [3], slowing down, etc. Contrary to humans, robots can change the parameters of their locomotion instantly to account for a new heading or to avoid obstacles. Therefore, even if bystanders trust that robots will not collide with them, these abrupt direction changes might be a source for distraction and discomfort.

We propose two sets of body cues to be *superimposed* on a robot through an AR HMD therefore decoupling appearance from mechanical build.

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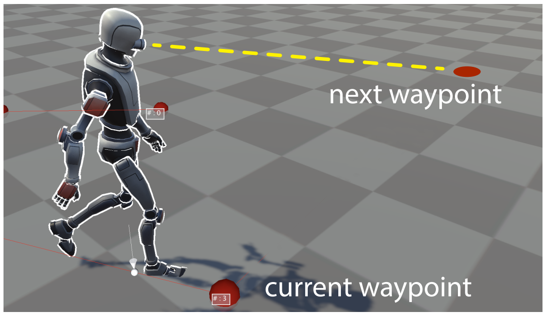
2 CUEING METHODS

Body: We opted for cues that are easy to interpret. Previous studies on steering situations found that humans typically align their head [4] with the next waypoint immediately following delivery of a direction change cue, before torso orientation so people expect such cues from others. This inspired the use of a humanoid avatar and the first two expressivity levels (Figure 1). The medium expressivity level (head and arm) is inspired by how cyclists signal their turn. The third level of expressivity involves the first two with additionally orienting the torso, to make the cue even more salient.

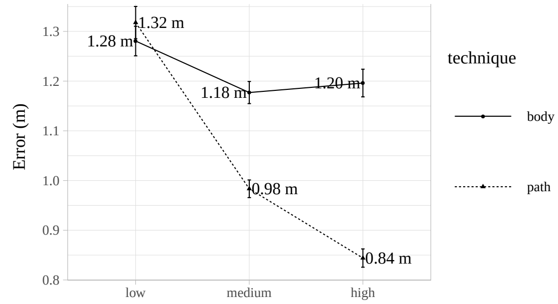
Path:Earlier works have explored visualising the path [5], yet these designs extend lines far into the future and in an MR setting, where many robots broadcast their paths, the visual field would become cluttered. As such, we use a shorter path with a pointed tip to indicate direction (Figure 1d). When a person is fixating forward while walking, the path of an adjacent robot will be outside the field of view. Bringing the path up to eye level might introduce unwanted obstruction. A further limitation rendering along the line of sight is that it is difficult to judge magnitude due to perspective. Our displayed path begins between the feet of the robot, meets the point where the robot will change direction and extends towards the next waypoint without reaching it (Figure 1d). We manipulate the length of the path as a means of manipulating *expressivity* in the *path* method (1,2 and 3 meters).

3 EVALUATION

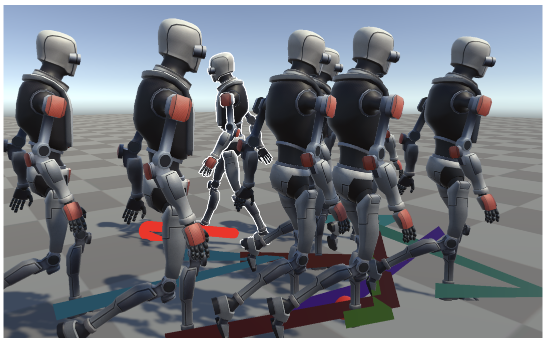
We explore how expressive these cues need to be, and how robust they are to occlusion with an experiment in VR with 14 participants: During the experiment the avatar walked short segments (1 m/s). Before reaching the end of a segment, the waypoint change cue would appear. Participants were instructed to point using their wand to indicate where they thought the next waypoint of the robot will be (following the direction change – Figure 2a). The robot turned and participants had to keep guessing for the next waypoints. When present, the occluding robots chose random waypoints ahead of the main robot avatar. The result was random occlusion and intersection of the main avatar's path.



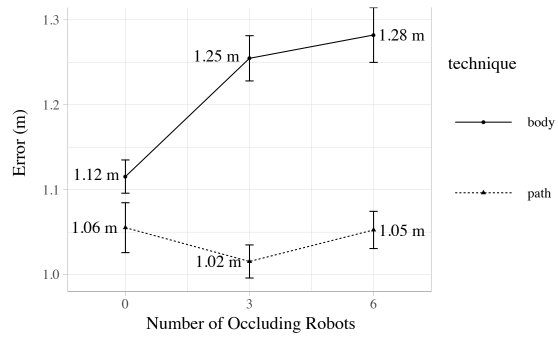
2 (a) Participants had to guess the next waypoint of the robot.



2 (b) Effect of cue expressivity level on Error.



2 (c) Six Occluding robots in the *Path* condition. The main robot avatar has a faint white outline for disambiguation.



2 (d) Effect of number of distractor robots on Error (lower is better). The body method was more sensitive to the number of distractors.

The experiment was a within-subjects design. Method was a factor with 2 levels, *Body* and *Path*. *Cue Expressivity* with 3 levels: low, medium and high and *Occluding robots* with 3 levels: none, 3 and 6. We recorded the prediction accuracy of participants, by recording the *Error*. i.e. The euclidean distance between the actual robot waypoint and the location the participant indicated with the wand.

4 RESULTS - DISCUSSION

Body/path had a significant effect on Error ($F_{1,13} = 20.78, p < 0.01$). Also number of distracting robots ($F_{1,13} = 6.12, p = 0.02$ - Figure 2d). *Expressivity level* also had a significant effect ($F_{2,26} = 25.5$, $p < 0.001$ - 2b). Participants were asked to rate both methods in terms of "Ease of Perception" on a 5-point likert scale. Summarizing the responses from the questionnaires (Kaptein method) shows that participants preferred the *Body* technique. We postulate this is because they are more natural to observe in contrast to an abstract rendering of a path.

As expected, cueing method (Body or Path) affected the participant's ability to accurately predict the waypoint. Using the *Body* method participants pointed on average 1.21m away from the robot's waypoint vs. 1.04 m from the path. A difference of ~17cm. Conversely, on the low expressivity level, when the path was shortest and the avatar only turned its head, the Body technique performed significantly better ($F_{2,26} = 21.3, p < 0.001$ - Figure 2b, leftmost column).

It is also notable that the length of the path resulted in a significant improvement in performance from the low to the high condition. The 3m path resulted in an average *Error* of 0.84 m vs. 1.32 m for the 1m path. i.e. *Error* and path length have a non-linear relationship and this suggests that MR interface designers should not extend the line too far into the future. This makes additional sense when considering that paths might be updated in response to external factors. The *path* method also proved more robust to visual occlusions than the *body* method. Specifically, the path technique's Error remained around 1.03 m despite the number of robots present on the scene (Figure 2d). In a busy environment with many robots present designers might use the path technique whereas when there are fewer robots they could opt to body cues alone. This is especially important considering that when robots are near, the path might be outside the person's field of view.

In conclusion, our findings suggest that both methods have strong points and interface designers should consider these strengths when choosing which technique to use. As future work, we are interested in matching the animation of the avatar to wheeled robots or other exotic locomotion methods.

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