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Abstract. We investigated the effects of role distribution on individuals' choice of reference frames in a two-person task. Pairs of participants had to move a virtual block in a constraint immersive virtual environment: only one of them could manipulate the object, his coworker guided him in the VE. Results show that the guiding operators used more addressee-centered frames of reference than the manipulators. They also suggest that the guides tried to facilitate the manipulators' actions by endorsing the cognitive load through the production of spatial utterances.

Keywords: Remote collaboration, common frame of reference, virtual reality

To deal with problems associated with large-scale environments, such as those found in the aeronautic industry, coworkers can now be remotely immersed in collaborative immersive virtual environments (CIVE) using virtual reality (VR) tools [1; 2]. However, a better understanding of collaboration is needed to improve and facilitate remote collaboration in CIVE [3].

Collaboration necessitates the building of a common frame of reference to allow people to exchange spatial information [4]. In this study we focused on the effects of role distribution on the choice of reference frames in spatial communication during a two-person spatial task.

1 Technical Description and Study Design

Twenty eight native French-language speakers participated in this study (6 women, 22 men; mean age 24 years, age range 20-54). They worked in pairs (6 male-female pairs, 8 male pairs). Two networked immersive displays were used (3.5m x 2.2m or 2m x 3m walls with rear double projection for stereoscopy and tracking system for parallax). Headset phones were used for verbal communication.
The task consisted of moving a block in a constraint virtual environment. Role distribution was asymmetric to force collaboration: one participant manipulated the virtual block while the other guided him in the VE. Both of them were represented by avatars. Before the collaborative session each participant received role-linked instructions and engaged in a training phase. Participants had 45 minutes to perform the task (i.e., move the block to the target places). All the sessions were videotaped and the conversations were digitally recorded. After the collaborative session, participants completed a questionnaire.

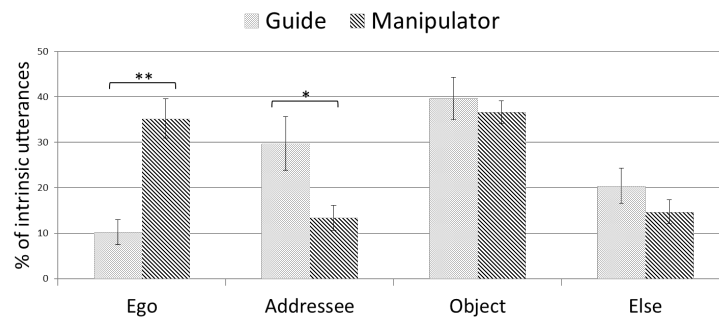Spatial utterances were classified according to the chosen reference frame (RF):
• General environment: when targets are located according to the general characteristics of the environment ("let's go to level 1").

• Intrinsic: when the utterance is centered on an origin and uses the related axes. This category is subdivided into four other subcategories, depending on the origin: ego- ("on my left"), addressee- ("behind you"), object- ("at the front of the plane") and else-centered (for other centered statements).

- Relative: when the relation depends on a ground and a point of view ("to the right of the table").

2   Results

No differences arose from the global classification comparison (general vs. intrinsic vs. relative) between the guides and the manipulators.

On the other hand, differences appeared in the intrinsic RF (Fig 1). The manipulators used significantly more ego–centered RF than the guides (respectively 35.2 and 10.2%, $t(18)= -4.91$, $p<.005$). The latter used significantly more addressee–centered RF than the manipulators (respectively 29.7 and 13.4%, $t(18)=2.505$, $p<.05$).

Fig. 1. Mean percentages of intrinsic utterances (Ego–, Addressee–, Object–, Else–centered) for the Guides and the Manipulators. Error bars represent S.E.M. * $p<.05$, ** $p<.005$

3   Discussion

In this study we analyzed choice of reference frames in a spatial collaborative task that was performed remotely using a collaborative immersive virtual environment. Pairs of participants moved a block within a constraint environment: one guided, whilst the other manipulated. Our results are consistent with previous studies in that they demonstrate that people spontaneously take the addressee's perspective [5]. Different studies have also shown that this perspective is modulated by different characteristics of the situation: action [5], orientation [6],

knowledge about the addressee [7]. Here, we have shown that taking the other person's perspective is a spontaneous trend that is modulated by role distribution. In our study, the participants who guided the action used more addressee-centered RF than the manipulators. Conversely, the manipulators used more ego-centered RF than the guides. These results are a first step towards highlighting the asymmetry of the cognitive workload in collaboration. Taking the manipulator's perspective would raise the cognitive workload of the guide during spatial communication. Further investigations are needed to link spatial communication and subjective workload.

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