Assessment of Interaction Quality in Mobile Robotic Telepresence: An Elderly Perspective

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Abstract In this paper, we focus on spatial formations when interacting via mobile robotic telepresence (MRP) systems. Previous research has found that those who used a MRP system to make a remote visit (pilot users) tended to use different spatial formations from what is typical in human-human interaction. In this paper, we present the results of a study where a pilot user interacted with ten elderly via a MRP system. Intentional deviations from known accepted spatial formations were made in order to study their effect on interaction quality from the local user perspective. Using a retrospective interviews technique, the elderly commented on the interaction and confirmed the importance of adhering to acceptable spatial configurations. The results show that there is a mismatch between pilot user behaviour and local user preference and that it is important to evaluate a MRP system from two perspectives, the pilot user's and the local user's.

Keywords F-formations, Mobile Robotic Telepresence, MRP systems, Quality of Interaction, Retrospective Interview, Spatial Formations, Spatial Configurations

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1 Introduction

Robotic telepresence offers the means to connect to a remote location via traditional telepresence with the added value of being able to teleoperate the robotic unit. A facet of robotic telepresence systems is social robotic telepresence. Their primary aim is to foster a social interaction between individuals. These systems are denoted as mobile robotic telepresence (MRP) systems. An example of a MRP system is Giraff, depicted in Fig. 1.

MRP systems could be particularly suitable for elderly with limited or no experience of computers. The device allows them to communicate in a natural and intuitive manner. The technology extends the means through which the elderly can interact with both professional caregivers and family/acquaintances at any place in the home. The elderly local users of the MRP system gain a greater level of security by adding a visual element to the interaction with security alarm operators, a service normally provided via the telephone line. Using the system, elderly can be seen by e.g. nurses, occupational therapists and physicians even without having to leave the home. The visual element allows the professional caregivers, the pilot users, to better assess the elderly people's situation. The pilot users also gain a greater level of control by being able to teleoperate the robot. However, the nature of MRP systems is complex. There are several types of interaction occurring simultaneously (see Fig. 2).

While many studies have reported on evaluations of MRP systems in an office environment [9, 13], few studies have examined the domain of the aging in place. Of these studies, some works examine the pilot user's perspective such as e.g. [6, 7, 11] and very few have examined the elderly people's perspective. Some notable exceptions include [2] that included 12 elderly who experienced using a MRP system both as local users and pilot users. In this paper, we discuss

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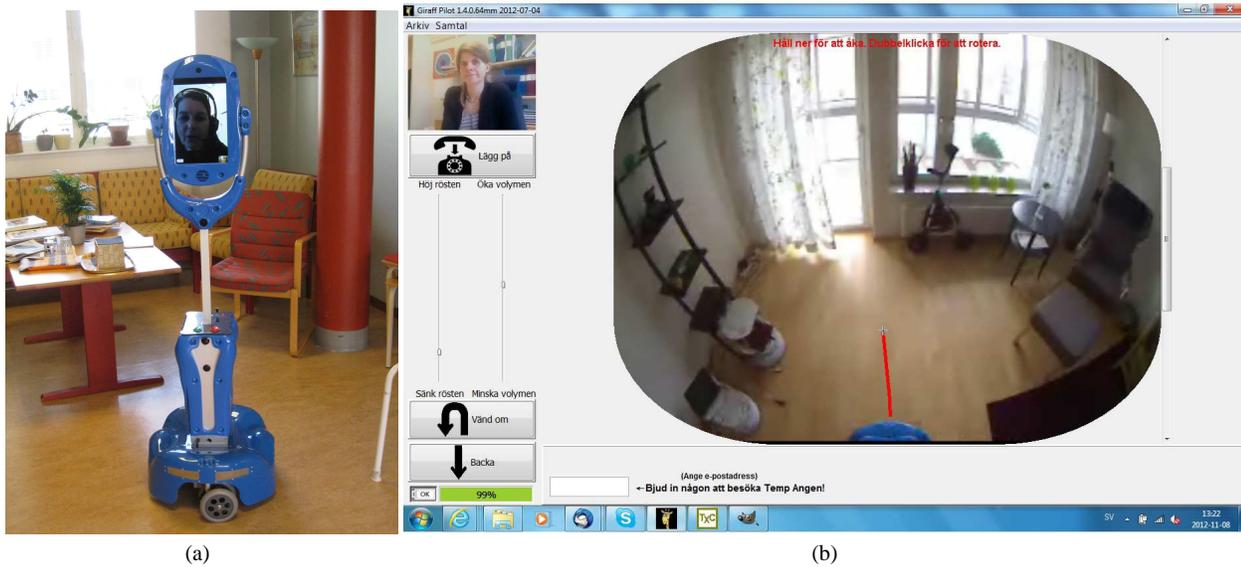
Fig. 1 (a) The Giraff robot. (b) The Giraff client interface v 1.4.

the results of two studies, one with novice pilot users maneuvering Giraff and one with elderly local users who for the first time interacted with a person embodied in Giraff. In the first study, it was found that the participants did not always adhere to the spatial F-formations defined by Adam Kendon. F-formations are spatial patterns formed in human-human interaction. In the second study, which is the main focus in this paper, a qualitative assessment of how such deviating behaviours were perceived by elderly local users was performed. The assessment included observations of the elderly people's behaviour and retrospective interviews during which elderly observed their own interaction. The combined results of the studies indicate that there is a mismatch in how the Giraff pilot users interact through the MRP system and how the elderly would prefer interacting. While many studies have reported on evaluations of MRP systems in an office environment [9,13], few studies have examined the domain of the aging in place. Of these studies, some works examine the pilot user's perspective such as e.g. [6,7,11] and very few have examined the elderly people's perspective. Some notable exceptions include [2] that included 12 elderly who experienced using a MRP system both as local users and pilot users. In this paper, we discuss the results of two studies, one with novice pilot users maneuvering Giraff and one with elderly local users who for the first time interacted with a person embodied in Giraff. In the first study, it was found that the participants did not always adhere to the spatial F-formations defined by Adam Kendon. F-formations are spatial patterns formed in human-human interaction. In the second study, which is the main focus in this paper, a qualitative assessment of how such deviating behaviours were perceived by elderly local users was performed. The assessment included observations of the elderly people's behaviour and

retrospective interviews during which elderly observed their own interaction. The combined results of the studies indicate that there is a mismatch in how the Giraff pilot users interact through the MRP system and how the elderly would prefer interacting.

2 Background

Kendon [5] distinguished three spatial formations (F-formations) that typically occur when interacting. The *vis-a-vis* is an arrangement formed by two individuals facing each other. The *L-shape* is generated when two individuals stand perpendicularly to each other facing an object and the *side-by-side* is when two or more participants stand (or sit) together looking in the same direction. Common for all F-formations is that there is a shared transactional segment to which two or more people direct their attention, the *O-space* (see Fig. 3). The F-formations are created subconsciously and occur naturally without any special intent from any of the people involved in the interaction.
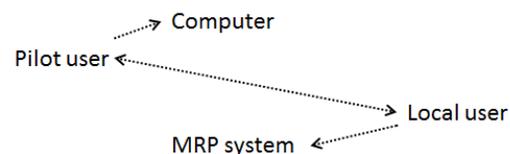
Fig. 2 Simultaneous interactions when using a MRP system.

Physical environments can limit and constrain opportunities for some shared activities, while encouraging others [10]. Features in a physical environment, e.g. doorways,
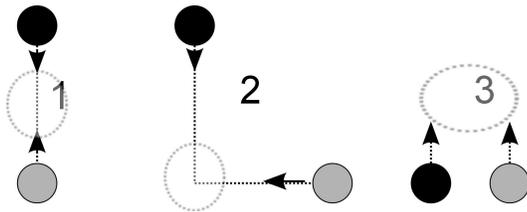
Fig. 3 The different F-formations distinguished by Kendon. 1. Vis-a-vis, 2. L-shape and 3. Side-by-side. The dotted ovals denote the O-space.

may discourage the creation of certain F-formations. Similarly, embodied constraints restrict what people can do based on the configurations of space and objects and make some behaviours more likely than others [3]. Being embodied in a MRP system can constitute an embodied constraint in that the physical properties of the system restrict particular behaviours. Pilot users may find it difficult to move backwards or to orient the robot in a proper way. A spatial configuration can limit the possibility to have eye-contact and detecting facial expressions while interacting. Eye-contact, physical proximity, intimacy of topic, smiling etc are factors that affect the level of intimacy in an interaction between humans [1]. Therefore, these same factors could potentially affect the intimacy in human-robot interaction (HRI).

In the field of HRI, a handful of works deal directly with Kendon's F-Formation system (e.g. [4, 7, 8, 12, 14]). Kuzuoka et al. [8] experimented with GestureMan-4, a teleoperated robot which can rotate the neck, waist and foot. The robot has one arm, a three-camera unit and a screen on its chest. In the robot's head, there is a built in speaker. They found that the orientation of the lower body of the robot had a dominant effect on reconfigurations of F-formations in an exhibit scenario.

In a previous study, [7] studied the interaction between 21 novice Giraff pilot users and an actor (elderly person) confined to a wheelchair. Giraff is a 163 cm tall MRP system (see Fig. 1) and consists of a mobile robotic base on which a 14.1" LCD screen, a web camera, speakers and a microphone are mounted. The camera has a wide-angle lens that provides the pilot user with a fish-eye view of the robot's environment. The field of view is 100° vertically and 160° horizontally. The pilot user steers the robot by pointing directly on the live video-feed and pressing the left mouse button. Turning around 180° is done by pushing a button. The experimental setup in [7] included a pre-defined scenario in a home-like environment. The actor positioned herself in the same locations and orientations for all participants. It was observed in the study that 33% of the novice pilot users (7 of 21) *looked away* while discussing a medical matter instead of forming a *vis-a-vis* (see an example in Fig. 4). The remaining 14 formed the *vis-a-vis*. Further, the pilot users who interacted in a *vis-a-vis* thought that it was easier to ma-

neuver the robot, e.g. make u-turns. One possible reason for the unexpected behaviour, other than problems with turning on spot can be the fact that the pilot had a fish-eye view of the robot's environment. This view allowed the pilot users to see the actor without physically turning the robot towards her. Once the actor was in view, the pilot user did not gain additional benefit from turning the Giraff and centering on the actor to create a vis-a-vis formation. Here is a potential problem, the local user may assume that the pilot user's view is the same (or worse) than the one that is normal in human-human interaction.

3 Study and Expectations

Expecting that spatial formations such as the *look-away* would not be perceived as acceptable by elderly local users, we designed an exploratory experiment to investigate how the use of different spatial formations during an interaction are actually perceived by elderly. We expected that Kendon's F-formations would also be applicable on interaction via MRP systems. Accordingly, the elderly were expected to adjust the spatial formation towards a *vis-a-vis* if the guide created the look-away formation observed in [7] in typical face-to-face situations. Further, it was expected that the elderly would reconfigure the spatial configuration towards an *L-shape* when talking about objects. We finally expected that the elderly would prefer to interact in F-formations since other formations limit the possibility to have eye-contact or detecting facial expressions.

4 Method

The study took place in the Ängen research and innovation apartment located in Örebro, Sweden. Ängen contains a rich set of devices that can be used in real homes. Participating in the experiment were three men and seven women. Their age varied between 61 and 82 (*M=72, SD=7.36*). Three participants had previously used video communication technologies or data/video games.

4.1 Experimental scenario

A researcher welcomed the elderly, who came one by one, to the apartment and asked them to sit down in the sofa. They were briefly informed about the Giraff (Fig. 1) and that they would be guided around by somebody being embodied in the Giraff. They were told that the tour would be filmed and that the videos would never be associated with them. The researcher left the room after the elderly had signed a consent form. The welcoming and information procedure took approximately 10 minutes.

Fig. 4 A screen shot from different angles of one of the pilot users doing the look-away formation seen in Kristoffersson et al. (2013).

Each elderly person experienced one of two scenarios which are detailed in Table 1. In each scenario, a person embodied in Giraff guided the elderly around the apartment. The guided tour consisted of four main steps: welcome in living room, showing objects in the kitchen, showing sensors in bedroom and showing objects in living room before saying good bye. The guide used language referents to describe each object. In **scenario a**, the guide interacted using mainly the F-formation *vis-a-vis*. In **scenario b**, she used other spatial formations (e.g. the look-away depicted in Fig. 4). In Fig. 5, the different spatial formations as created intentionally by the guide are shown in terms of how Giraff and the elderly were initially oriented in each of the four steps in the two scenarios. In total, five elderly experienced **scenario a**, three experienced **scenario b** and two interacted with the guide simultaneously. Each guided tour lasted for approximately 10 minutes.

4.2 Retrospective interview

Immediately after having completed the tour, the researcher returned and asked the elderly person to follow to a nearby office. The researcher showed a video recording of the interaction between the elderly person and the person embodied in Giraff during step 1. Next, he asked a set of questions closely connected to step 1 (see Table 2). The interview continued in the same manner for each of the four steps (see Table 3,Table 4 and Table 5 respectively). The questions asked after each video had strong similarities. To exemplify, the elderly were asked to respond to a question about how it felt to talk to the guide during each specific step. The length of the recorded videos shown for each step varied between 90 s and 396 s. The length of each interview was approximately 40 min and recorded using a mp3-player.

4.3 Qualitative data analysis

The data collected during the experiment consist of videos and voice recordings. For each elderly person, there was one movie per step in the scenario. A series of snapshots were extracted for each elderly and step. The analysis of the videos assessed how the elderly were spatially configured with respect to the Giraff and whether they spatially

reconfigured themselves with respect to Giraff and objects described during the guided tour.

We believe that the use of a retrospective interview methodology allows for a more elaborated assessment of how the elderly perceived the interaction than what would have been possible to extract from a normal questionnaire form. As will be shown in Ex. 7 and Ex. 10, the elderly person's perception of the interaction changed during the tour. Had she not been interviewed using the retrospective interview methodology, it is likely that such changes would have been undetected. Further, even though the interview contained many questions that were to be answered on a Likert scale, the elderly people's response were more elaborated than just a number. For example, they responded with usability aspects, e.g. unsharp image or bad sound, when asked about if the interaction felt natural in a certain step. Only a qualitative analysis of the response on questions related to step 1-4 was performed. The methodology allowed the elderly to motivate each response and the researcher performing the interview to assess whether the elderly had understood the questions correctly.

5 Results

Using the results of the qualitative analysis, this section focuses on: (a) how the elderly reconfigured the spatial configurations depending on scenario and (b) what spatial formations that are preferable among the elderly. The results of the analysis will be exemplified by the elderly people's response during the retrospective interviews and by snap shots from the videos. The examples are followed by a parenthesis (P#:i,ii,iii) where P# is an elderly id, i is the scenario, ii is the step and iii is the question asked.

5.1 Reconfigurations of spatial formations

The elderly experiencing **scenario b** adjusted their spatial configuration with respect to Giraff towards a *vis-a-vis* during the first encounter in step 1. Fig. 6 (a-c) shows three participants in their upright sitting postures; note that in (d-f), all have leaned forward and increased their head turn angle. This behaviour did not occur amongst the elderly experiencing **scenario a** in which the guide positioned Giraff in a *vis-a-vis* configuration.

Table 1 The experiment scenarios a and b. S1-S4 denote the four steps.

Scenario a ("F-formations")	Scenario b ("other formations")
S1. The guide undocked the Giraff and drove away to talk to the elderly person while...	
facing the elderly person (vis-a-vis).	*looking at the middle window O5 (look-away).*
S2. The guide asked the elderly person to follow to the kitchen in which she showed a number of objects including the robot Bestic (O1) situated on and around a table while being...	
turned towards Bestic (L-shape/vis-a-vis).	*turned towards a clock on the wall (look-away).*
S3. The guide asked the elderly person to follow to the bedroom that contained sensors spread around in the room and on a bed. In here the guide ...	
faced the elderly person (vis-a-vis).	*faced the bed (look-away).*
S4. The guide drove back to the living room and asked the elderly person to sit in the sofa again. Now the guide talked about different objects, e.g. dosett, paintings (O2), Roomba (O3) and robotic table (O4) while it...	
faced the elderly person (vis-a-vis).	*Looked at the middle window (05) look-away).*
The guide then said bye and returned to the docking station.	

| (a) Scenario a | (b) Scenario b |
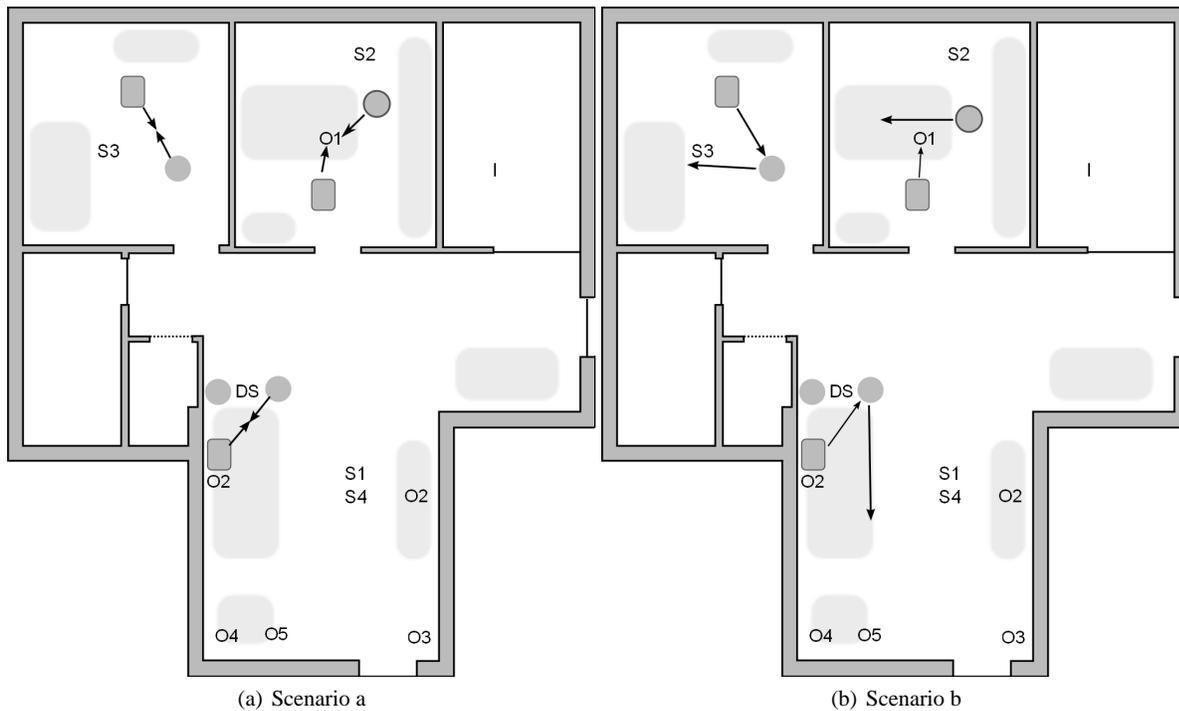
Fig. 5 A graphical overview of how Giraff was oriented with respect to the elderly in **scenario a and b**. Giraff is a circle. Elderly person is a square. The arrows show how Giraff and the elderly person were oriented. S1-S4 denote the location for the steps. O1-O5 denote objects. DS denotes docking station. I denotes the room where the retrospective interview took place.

Table 2 Questions in Retrospective Interview for Step 1

1.	How did it feel do talk to the one driving Giraff?
2.	How should Giraff have been turned? (as it was now or differently)
On a scale 1-7 where 1 = Do not agree at all and 7 = Fully agree	
When the person in Giraff connected and drove to meet you it felt as if...	
S1_a.	the person's attention was directed at you
S1_b.	the person was interested in meeting you
S1_c.	I would have wanted the person in Giraff to be oriented in another direction

Table 3 Questions in Retrospective Interview for Step 2

3.	How did it feel do talk to the one driving Giraff when it talked about the robot Bestic and the chairs?	
4.	Did it feel natural to talk in the kitchen?	
5.	How should the Giraff have been turned? (as it was now or differently)	
On a scale 1-7 where 1 = Do not agree at all and 7 = Fully agree		
When the person in Giraff drove into the kitchen and described the robot Bestic if felt as if...		
S2_a.	the person really wanted to describe what was there	
S2_b.	the person was focused at you	
S2_c.	the person really was thinking about something else	

Table 4 Questions in Retrospective Interview for Step 3

6.	How did it feel do talk to the one driving Giraff when it talked about the things that were in the bedroom?	
7.	Did it feel natural to talk in the bedroom?	
8.	How should the Giraff have been turned? (as it was now or differently)	
On a scale 1-7 where 1 = Do not agree at all and 7 = Fully agree		
When the person in Giraff drove into the bedroom and described what was in there if felt as if...		
S3_a.	the person really wanted to describe what was there	
S3_b.	the person was focused at you	
S3_c.	the person really was thinking about something else	

Table 5 Questions in Retrospective Interview for Step 4

9.	How did it feel do talk to the one driving Giraff when it described the dosett and paintings in the living room?	
10.	How should the Giraff have been turned when you sat in the sofa? (as it was now or differently)	
On a scale 1-7 where 1 = Do not agree at all and 7 = Fully agree		
When the person in Giraff followed you to the sofa again and talked to you if felt as if...		
S4_a.	the person really wanted to talk about the dosett	
S4_b.	the person's attention was directed towards you	
S4_c.	the person really was thinking about something else	
S4_d.	the person thought that it had been nice to see you	
11.	Did you feel comfortable with the tour in the apartment?	

Interacting with a person in Giraff such as in **scenario b** can be confusing. This was expressed by P8 when watching herself on video, see Ex. 1 and Fig. 7. To preserve the anonymity of the participant, her face has been masked out.

(Ex 1) [..] I did not see her facial expressions and so on and therefore I tried to move myself to see better and then it turned out that I should have continued to stay there because that was the thing she was gonna talk about. (P8:b,2,movie S2)

Irrespective of the scenario, the elderly reconfigured the spatial configuration when interacting by looking at the objects rather than the Giraff in step 3 and 4. Fig. 8 shows how two of the elderly experiencing **scenario b** adjusted their configurations while talking about objects. They also ended the interaction standing in a *vis-a-vis* with the robot.

5.2 F-formation preference when interacting via MRP systems

The elderly expressed that eye-contact is necessary when interacting via MRP systems (see Ex 2, 7 and 8). As shown in Ex. 2-5, the elderly experiencing **scenario a** seem to have noticed that the guide had turned the Giraff towards them.

(Ex 2) Eye-contact was there and I believe that is important. (P2:a,1,S1_1)
(Ex 3) Like it was now so one can see the person. (P3:a,2,5)
(Ex 4) I felt as if the camera was directed at me. It almost looks like that. (P6:a,3,8)
(Ex 5) Yes so that I see the person. I think that is very important if one should have this for real so that one does not just talk to a machine. (P3:a,4,10)

Some participants experiencing **scenario b** expressed that they felt unaccustomed to interact through a MRP-system (Ex. 6-7). Others expressed that Giraff should have been turned in a different way (Ex. 8-9) and reconfigured towards a *vis-a-vis* (Fig. 6).

The preferred spatial formation seems to be situation dependent. While the *vis-a-vis* was initially important for the elderly (see Fig. 6 and Ex 8), it seemed to decrease in importance during step 3 and 4 where the guide spoke about different objects (see Ex 10). Irrespective of the scenario, the elderly expressed that Giraff was turned appropriately or better than in step 1 (see Ex 11). Now, as previously described,

(a) P4 a   (b) P5 a   (c) P8 a

(d) P4 b   (e) P5 b   (f) P8 b

Fig. 6 Snapshots of how the elderly P4, P5 and P8 reconfigured themselves spatially during step 1 **scenario b**.

Fig. 7 Snapshots showing how an elderly (P8) was confused on where to stand in the kitchen, step 2. The person adjusted the spatial configuration.

(a) P5 a   (b) P5 b   (c) P5 c

(d) P8 a   (e) P8 b   (f) P8 c

Fig. 8 Snapshots of how the elderly P5 and P8 reconfigured themselves spatially when interacting about objects in **scenario b** step 4. Left column pictures show their initial position in step 4. Middle column pictures show how they watched an object. Right column show their goodbye configuration.

the elderly reconfigured themselves spatially by looking at the different objects (see Fig. 8). This can be compared to the F-formation *L-shape* which is typical when talking about objects in human-human interaction.

(Ex 6) I felt a little unaccustomed. (P5:b,1,1)

(Ex 7) It was a bit difficult with eye-contact with that robot but that is also because of being unaccustomed [..] it is somehow not a real human. (P4:b,-,S4_15)

(Ex 8) Yes, one must always have eye-contact [..] I think the person in the Giraff needs to think about that. I did not have eye-contact all the time [..] but I tried moving so that I could see [..]. (P8:b,1,2)

(Ex 9) Well, it [Giraff] did not have contact with me, it had contact with the working desk or the bed. [..] I do not sit like this and talk to you. (P5:b,3,8)

(Ex 10) No I think it [Giraff] was turned good. She was standing there and I was sitting there so that was good I think. (P4:b,4,10)

(Ex 11) Better than the first time. (P5:b,4,10)

6 Conclusions

In this article, ten elderly were guided around an apartment by a person embodied in a Giraff robot. The guide positioned the robot in spatial configurations that are typically occurring in human-human interaction with five of the participants. The others were guided around while the guide used a *look-away* configuration. This formation had previously been observed in [7] in which novice pilot users maneuvered Giraff. A spatial configuration such as *look-away* can limit the possibility to have eye-contact and detecting facial expressions while interacting. Eye-contact, physical proximity, intimacy of topic, smiling etc are factors that affect the level of intimacy in an interaction between humans [1]. Therefore, these same factors could potentially affect the intimacy in human-robot interaction (HRI).

The results of our qualitative analysis of the videos used in the retrospective interviews and the transcriptions of them indicate that it is important for elderly to have eye-contact with the person embodied in Giraff. Elderly were observed to reconfigure the spatial formation towards a *vis-a-vis* particularly in the initial step of the guided tour which included welcoming the elderly (see Fig. 6). In later steps, when the guide talked about objects spread around in the room, the elderly oriented themselves towards the objects described rather than towards the Giraff (see Fig. 8). These orientations (although the Giraff did not turn during the interaction in any step) can be compared with the *L-shape*. Although it can be argued that a *vis-a-vis* between a MRP system and a local user does not automatically imply that there is eye-contact, the orientation of the robot with respect to the elderly can increase or decrease the elderly people's possibility for eye-contact.

The elderly both showed and stated that it is important for local users to see the pilot user while interacting. Thus it is important that pilot users adhere to acceptable spatial

formations (F-formations) while using a MRP system. Since these formations were not always created in [7], there is a need to facilitate the Giraff's rotation procedure by adjusting the pilot interface. There is also a need to guide the pilot users towards using the spatial formations that are preferred by the local users.

In summary, the combined results of the two studies indicate that there is a mismatch in how the Giraff pilot users interact through the MRP system and how the elderly would prefer interacting. The study emphasizes the importance of evaluating a MRP system from two perspectives, the pilot user's and the local user's.

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