Robotic tele-presence with DARYL in the wild

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ABSTRACT

This paper describes the results of a qualitative analysis of questionnaire data collected during a public exhibition of our robotic tele-presence system. In Summer 2013 the mildly humanized robot DARYL could be tried out by the general public during our University's science fair in the city center. People were given the chance to communicate through the robot with their peers and to perceive the world through the "eyes" and "ears" of the robot by means of a head-mounted display with attached headphones. An operator's voice was instantaneously transmitted to the robot's location and his or her head movements were tracked to enable direct, intuitive control of the robot's head movements. Twenty-seven people were interviewed in a structured way about their impressions and opinions after having either operated or interacted with the tele-operated robot. A careful analysis of the acquired data reveals a rather positive evaluation of the tele-presence system and interesting opinions about suitable application areas. These findings may guide designers of robotic tele-presence systems, a research area of increasing popularity.

Author Keywords

robotics; tele-operation; survey; head-mounted display

ACM Classification Keywords

I.2.9 Robotics: Operator interfaces; J.4 Social and behavioral sciences: Sociology

INTRODUCTION

Recently, many new robotic telepresence systems have been advertised to be released to the global market. They are supposed to be used by the general public affording only a short initial training phase. By "replicating a person in a distant location" they are advertised as helpful tools in domestic and professional domains including remote working, assisted living or telemedicine. A key promise of such systems is that they allow to cut down travel costs because users can remotely meet face-to-face embodied as a robotic avatar.

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As with many other technological advancements these claims remain to be tested. Are the different operator interfaces really so well designed that they can be used intuitively and efficiently by non-professionals? Are these systems indeed appropriate substitutes for face-to-face meetings under all possible conditions? What does the general public think about a future with remote controlled robotic avatars?

The remainder of the paper is structured as follows. In the next section related work is going to be introduced and discussed, before the system setup is presented. This is followed by a description of the general scenario that the visitors of the science fair were invited to take part in. Subsequently, the data collection methodology will be detailed and results of a qualitative analysis of the interviews are presented. Finally, conclusions are drawn and possible implications for the applicability of robotic tele-presence systems are discussed.

RELATED WORK

Apart from prominent product announcements (as discussed in [6], e.g., Ava by iRobot, Beam by Suitable Technologies (former Texai by Willow Garage), VGO by Vgo Communications, Giraff by HeadThere, RP-VITA by InTouch Health, TiLR by RoboDynamics, Double by Double Robotics) telepresence robotics is also a hot topic in academic research. In the following an overview of recent work is given.

Indications for the usefulness of HMD-based teleoperation of humanoid robots have been found even for rather passive remote social interaction. A participant embodied as a robot significantly increases a presenter's feeling of being listened to as compared to a video conferencing setup [8].

The 'Giraff' mobile telepresence robot together with a console interface [7] was utilized in a study of a task featuring social and mainly physical interaction (monitoring elderly people). Both spatial and social presence felt by the operator were assessed using questionnaires and, because the Giraff robotic platform is mobile, the study focused on six types of formations realized by the robot operator together with the interlocutors. A number of correlations between the operator's spatial/social presence and these formations are reported, which are interesting even though they were detected post-hoc. They also employed an actor to act in the role of the remote partner making it unfeasible to collect and analyze impressions from remote interaction partners.

The mobile robot "Robonaut" [5] has been tele-operated by means of sophisticated tracking and wireless video transmis-

sion of stereo video feeds. The subjective experiences, described only on an informal level, indicate that an HMD-based interface is easy to manage and intuitively operated.

Thirty-two participants used the "double telepresence robot" to collaboratively construct either small or big versions of a geometrical object in a two-by-two empirical study [9]. The impact of operator mobility on task performance and presence was investigated. Although an operator's feeling of presence is higher in the two mobile conditions (as compared to the two stationary conditions), task completion times were on average significantly lower for the two high-mobility tasks as compared to the low-mobility tasks. Again, no measures regarding overall ease of use or user satisfaction were taken in this study.

During a public demonstration of the highly anthropomorphic android robot "Geminoid HI-1" at Ars Electronica a survey of visitors, who had interacted with the tele-operated android, revealed mostly positive attitudes towards this type of interaction device [4]. In addition, results of an empirical study [10] indicate that Geminoid HI-1 can remain unnoticed in a public space suggesting the possibility that the illusion of social presence can be achieved by sophisticated design alone.

Results of a previous empirical study in a laboratory environment [2, 3] suggest that using a head-mounted display (HMD) to tele-operate the mildly humanized robot DARYL in many respects outperforms the use of a standard console interface. Especially, subjective evaluations of an operator's spatial and social presence were significantly higher when an HMD was used as compared to a console.

All these works carry out laboratory studies which are commonly known to be prone of a selection bias regarding the participants' backgrounds and motivations. In this work, however, we take our tele-presence system into the wild collecting data from ordinary people in a public space in the aim to complement the insights gathered from a previous laboratory study [2].

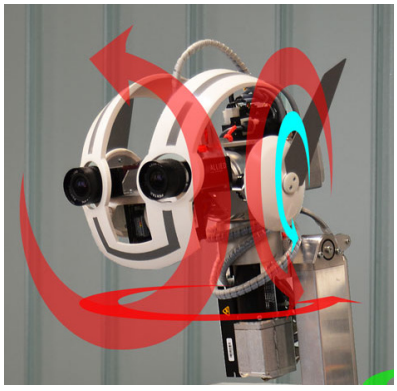

Figure 2. The head unit of the mildly-humanized robot DARYL with annotated degrees of freedom.

SYSTEM SETUP

Fig. 1 shows two views of the setup realized at the exhibition of the tele-operation system during the public science fair in Summer 2013 in the city center of Freiburg, Germany. The operator (see bottom of Fig. 1(a) and left side of Fig. 1(b)) wears Sony's head-mounted display "HMZ-T1" with a "Colibri" inertial measurement unit mounted on top of it.

The robot DARYL features several degrees of freedom in wheels, torso and head, three of which are used by our telepresence setup (cf. Fig. 2). Two cameras in the robot's eyes and two binaural microphones in the robot's ear-like modalities provide stereoscopic vision and hearing.

Thereby, the operator can see herself from the back through DARYL's two cameras. She can also intuitively change the robot's viewing direction by turning hear head accordingly in all three dimensions. A small wireless microphone allows the transmission of the operators voice and DARYL's stereo microphones let her hear the surroundings of the robot. A more detailed technical description of this setup is provided elsewhere [2].

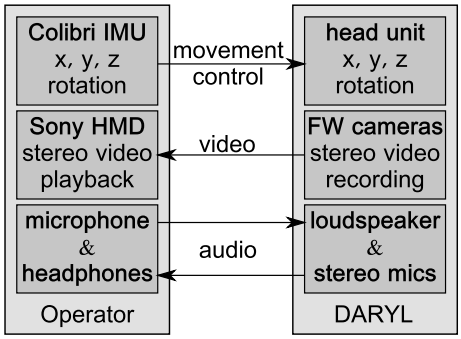

Figure 3. System schematics

A schematic of the connections between the operator and the robot DARYL in presented is Fig. 3. Only audio transmission is bi-directional with the limitation that the operator's voice is transmitted to the robot's location monophonic, whereas a stereophonic transmission is realized for the direction from the robot to the operator. Together with stereo video transmission in the same direction highest levels of social presence can be achieved [2].

SCENARIO DESCRIPTION

The science fair took place in the center of Freiburg city mainly inside show tents. We were provided with an area measuring two meters by four meters in total. Only one side of this area was closed by a partition panel leaving enough opportunity for visitors to see our robotic tele-presence setup from a distance.

Accordingly, visitors of the science fair could always engage the staff during the opening hours from 10am until 6pm on both exhibition days, July 12 and 13, 2013. Under such circumstances, a controlled study is hard to carry out soundly. Thus, we decided to target groups of at least two people and let them freely try out the system. In most cases only one of them operated the robot (N=23) and all others interacted with him or her through the robot. Sometimes, however, people took turns with operating the robot so that these people reported on their impressions from both perspectives (N=4).

(a) Overhead camera view (b) Side view with the operator to the left and the operated robot to the right

Figure 1. The robot DARYL installed at the science fair operated by a visitor

DATA COLLECTION

After their experience with the tele-operation system every group was asked, if they were willing to report on their feelings and impressions by taking part in a short interview. The scientific background of this interview was explained to them and, if they agreed (which was the case for all visitors that we asked), the interview was recorded using digital audio equipment.

A total of twenty-seven visitors (17 male, 10 female) agreed to be interviewed. Fifteen (11 male) had only operated the robot DARYL, eight (three male) only interacted with it, and four (three male) had done both before the interview began. On average the participants were 30 years old (standard deviation (STD) 15 years) and the majority of them (N=18) described their friendship relationship with the person they had just interacted with as "very good" (as opposed to "good", N=3, and "none", N=6). For all 27 visitors except one this was the first time to see the robot DARYL face-to-face and, again, the majority of them (N=23) had never heard of or read about this robot before.

After this background data was collected, the subsequent open-response part of the interview consisted of the following four sections:

1. Please describe the robot "DARYL".

2. Did you hesitate to participate in the experiment? Please elaborate.

3. How did you feel, when you had the conversation with another person through DARYL?

4. Do you believe that robots such as "DARYL" could be used in the future to participate in meetings/conferences in another country? Which other applications could you possibly imagine for this technology?

With this we followed a very similar interview structure used in previous research on the "uncanny valley" employing the android robot "Geminoid HI-1" in a public exhibition [4]. The resulting audio files were transcribed and a qualitative analysis of these interviews is presented next.

QUALITATIVE ANALYSIS

1. Descriptions of DARYL

At first, visitors described the robot DARYL in their own words. Their descriptions are summarized here distinguishing positive and negative adjectives.

As can be seen in Table 1, the descriptions of many visitors included technical descriptions (N=11), which are rated as neutral adjective in this list (N=16). In summary, the descriptions contained far more positive (N=28) than negative adjectives (N=4).

Interestingly, some visitors chose to describe the robot positively but in a way that could imply a negative attitude, because they negated a negative adjective such as "scary" or reported their "surprise". It also seemed difficult for some to focus on describing the robot and not their experience with it, as in case of those who reported, for example, a "strange feeling" or "jerking".

2. Hesitation to participate

Of all 27 visitors only two reported having hesitate for a moment before trying out the system. The remaining 25 visitors stated not having hesitated at all.

3. Feelings during conversation

The most frequently reported feeling "strange" is not necessarily a negative one, because it can be described as both being curious, which is a slightly positive feeling, and embarrassed, a slightly negative feeling [11]. Even when "strange" is being counted as negative, the number of positive feelings

adjective	positive	negative	neutral
technical			11
funny	7		
human-like			5
interesting	4		
fascinating	3		
friendly	2		
good looking	2		
very good	2		
frightening		2	
jerking		1	
strange feeling		1	
beautiful	1		
clever	1		
cool	1		
innovative	1		
not scary	1		
reacts very fast	1		
impressive	1		
surprising	1		
$\sum$	28	4	16

Table 1. List of adjectives derived from descriptions of the robot DARYL sorted by total count and split up into positive, negative, and neutral connotations respectively. Visitors, who provided longer descriptions, contributed more than one adjective to this list.

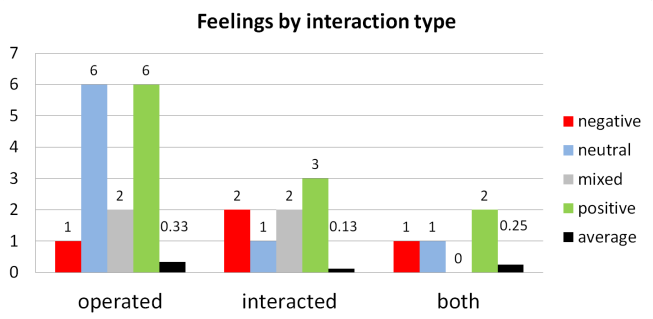

Figure 4. Bar plot showing the interaction between self-reported overall feeling and interaction type group

(55%) outweighs the sum of the negative (31%) and the neutral feelings (14%) listed in Table 2.

The bar plot presented in Fig. 4 presents a summary of the acquired data cross-correlated with the "interaction type" of each participant. First, for each participant's answer it was determined whether it contained only *negative* adjectives, both positive and negative adjectives (labeled *mixed* in Fig. 4), only *positive* adjectives, or purely *neutral* ones. This was then cross-correlated with the participant either only having *operated* the robot, or *interacted* with it, or *both*. In addition, the normalized *average* is calculated per interaction type (int_type) according to the formula:

$$N_{avg}(int\_type) = \frac{-1 \times N_{neg}(int\_type) + N_{pos}(int\_type)}{N_{total}(int\_type)}$$

In effect, the data suggests that the system was evaluated most positively by those participants who had solely operated the

feeling	positive	negative	neutral
strange		7	
fascinating	4		
like Skype or better	4		
funny	4		
normal			3
jerky		2	
unusual		2	
alien		1	
insecure		1	
amusing	1		
exceptional	1		
impressive	1		
works very well	1		
interesting	1		
comfortable	1		
close to partner	1		
curiosity	1		
positive	1		
nice	1		
great	1		
changing perspective			1
direct			1
present			1
$\sum$	23	13	6

Table 2. List of feelings reported by the visitors when being asked about how they felt during their remote conversation sorted by total count and split up into positive, negative, and neutral connotations. Visitors, who provided long answers, contributed more than one token to this list.

robot DARYL ($N_{avg}(operated) = 0.33 > N_{avg}(both) = 0.25 > N_{avg}(interacted) = 0.13$). However, the rather low number of participants per interaction type needs to be taken into account when critically assessing the general value of this result.

4. Future applications

A summary of all applications discussed and/or proposed by the visitors is presented in Table 3. It is not surprising that *conference* was mentioned and discussed very often, because the questionnaire item mentioned this application as an example of a particular application. Therefore, the fact that on average two out of nine participants responded negatively to this proposition seems most informative.

Interestingly, six individuals independently came up with the idea of using this system for *emergency management* and another four even considered an application *at home* possible. Both of these application scenarios were not even once judged as inappropriate, whereas health care-related applications, such as working in the *hospital* or taking care of *disabled persons*, were much more controversial.

CONCLUSIONS AND DISCUSSION

We set out to test our HMD-based robotic tele-presence system with regard to the general population's degree of acceptance, their subjective feelings, and their opinion of its usefulness in real-world applications. On average more positive

application type	yes	no
conference	14	4
emergency management	6	0
at home	4	0
skype++ / video conference	3	1
site inspection	2	0
hospital	2	1
disabled person	2	1
assisting disabled person	1	0
space	1	0
mining	1	0
computer games	1	0
entertainment	1	0
shopping	1	0
in the movies	1	0
$\sum$	42	7

Table 3. List of applications that were deemed appropriate (yes column) or inappropriate (no column) for the tele-presence system sorted by total count. Again, visitors giving long answers potentially contributed more than once to this list.

than negative responses were given regarding, both, the general likability of the robot DARYL itself as well as the feelings whilst tele-operating it. Also, nobody seemed to have hesitated to try out the system, which might indicate that the robot is not perceived as threatening and the whole system is expected to be intuitive to use.

When asked about possible applications of such a system, it is surprising that health-care applications (e.g. in a hospital as proposed by [7] or in a day care center for the elderly [12]) are seen very critical by the public. Of course, this might only be the case for this particular robotic setup. However, other applications such as "emergency management" might be better accepted and, thus, should be investigated and developed further.

In the light of previous results on social and spatial presence [2], we have to admit that DARYL's appearance might be too far away from human-likeness to expect similarly strong body ownership transfer as found for HMD-based tele-operation of Geminoid HI-1 [1]. Nonetheless, this expectation is one more piece of the puzzle, which is going to be investigated in future studies on the effects of cross-combining operator modalities with robotic embodiments [3].

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