

**SIXTH FRAMEWORK PROGRAMME
PRIORITY 2**



Information Society
Technologies

Specific Targeted Research Project

ROBOT@CWE

Advanced robotic systems in future collaborative working environments

Contract Number 034002

**Deliverable 3.4-7: Preliminary report on usability,
social acceptance, user experience and societal impact
evaluation**

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Deliverable Administration & Summary			
Deliverable	No.	Name	
	D3.4-3.7	Preliminary report on usability, social acceptance, user experience and societal impact evaluation	
Workpackage	No.	Name	
	WP3	<i>Robotic – CWE interfaces and evaluation of impacts</i>	
Task	No.	Name	Description from DOW
	T3.2	<i>Usability and user experience aspects</i>	One of the main objectives of this project is to design IST-robotic systems that correspond to the users' needs concerning the interaction and collaboration with such systems. Thus, this task is concerned with the gathering of the users' requirements, the conception of prototypes for robotic user interfaces and their evaluation against the requirements. Usability is mainly concerned with the ease of use and effectiveness of interactive systems. User experience widens this concept with emotional and social aspects like engagement, fun and aesthetics. User experience also contributes to effectiveness due to the fact that employees are likely to work better if they enjoy their work and the systems they have to interact with. We will apply and adapt methods from usability engineering, user-centered system design and experience and application research, such as usability testing, focus groups and interviews. In this way we will explore, design and evaluate user interfaces for IST-robotic systems from the user's point of view with a high quality regarding usability and user experience.
Task	No.	Name	Description from DOW
	T3.3	<i>Acceptance of IST-robotic integration within CWE</i>	The acceptance of IST-robotic systems is mainly based on the usability as well as on the perceived usefulness within collaborative work environments. Further acceptance aspects are individual and demographic properties of the users as well as their social environments within an organization. The evaluation will be conducted in close cooperation with industrial partners using questionnaires, observation and interviews. The challenge is to evaluate the acceptance of technological systems which are different from common information technologies in the work environment. First, the users are not yet familiar in the usage and interaction with IST-robotic systems and second these systems have far more anthropomorphic capabilities than common information technologies, which lead to more intense and social reactions of the users.

Task	No.	Name	Description from DOW			
	T3.4	<i>Societal studies</i> ROBOT@CWE <i>concepts</i>	<i>impact</i> of	<p>The goal of this task is to analyze the impact of robotic systems beyond the organizational level focusing on the societal level of Europe. The societal impacts can be manifold, influencing not only areas such as technology but also ecology, economy, policy and culture. Issues such as sustainability, rationalization, digital divide or privacy but also changing norms and values will be investigated. The overall objective is to work out recommendations, based on detailed analyses of the five aforementioned areas, for a sustainable and socially compliant human-robot interaction design.</p> <p>The impact of developed technologies in the real applications in close collaboration with industrial partners is a further objective of this task. Different scenarios (construction, service) and prototypes will be selected in order to check the acceptance of IST-robotics systems by workers and companies' organizational models. The environmental impact of these technologies will be also analyzed.</p>		
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1. Executive Summary

This preliminary evaluation report presents the first insights gained in ROBOT@CWE on usability, social acceptance, user experience and societal impact based on the performed evaluation activities. After an introduction (chapter 2), more details on each evaluation factor and the general methodological approach can be found in chapter 3. In chapter 4 the evaluation set-ups of all the case studies are described in detail. The chapters 5 until 9 present a comparison between the different user studies and the insights gained on the evaluation factors. Recommendations and lessons learned will be presented in chapter 10. A summary and outlook on upcoming evaluation studies planned for the last project year concludes this deliverable. In addition, all raw data reports and videos for each evaluation activity are available as power point presentations on the internal ROBOT@CWE website under the following link: <http://robot-at-cwe.eu/> (Document repository, WP3).

1.1. *Link with the objectives of the project*

The overall objective of the evaluation activities in the Robot@cwe project is to investigate if **people positively experience robots as support for collaboration and accept them as part of the future society** (see D1.3@M6). Within this deliverable the focus is on the first insights on usability, social acceptance, user experience and societal impact, which contributes to the project by:

1. Evaluating, the different platforms used in the Robot@cwe project in terms of usability, social acceptance, user experience and societal impact by means of several case studies
2. Defining the important influence factors based on these case studies for the integrated scenario of the Robot@cwe project

The deliverable provides an overview on all performed evaluation activities. Based on the gathered data, the main goal was to understand and interpret the evaluation results with regard to the defined USUS evaluation framework (see D1.3@M6) in order to find out how people perceive the robotic systems. All evaluation results together are used for a comparison of the different applications in different sectors. Apart from the evaluation activities presented in this deliverable, final evaluation results on the pre-studies and final study of the integrated scenario, on expert interviews on societal impact, on a cognitive walkthrough through the videos of all user studies, and on an online survey on user experience and social acceptance with 300 participants will be presented in D4.6@M36.

1.2. *State of the Art*

Evaluation of how people will interact, accept and communicate with robots has started even before humanoid robots could be built. Science fiction literature has developed various concepts and ideas on how human society might interact with robots and how society will be influenced by the introduction of robots. Today humanoid robots are becoming available and collaborative work with this form of robots has to be investigated not only in terms of usability –focusing on making interaction more efficient and effective– but looking at

influencing factors like user experience, social acceptance, and finally looking at the societal impact of the introduction of humanoid robots.

A lot of work already has been done in terms of assessing the usability of robotic systems with regard to effectiveness, efficiency, learnability, flexibility, robustness, and utility. Similarly more and more studies pay attention to (social) acceptance and user experience/perception studies in Human-Robot Interaction (more details on related work in these areas can be found in Weiss *et. al* (2009) and Weiss *et. al* (2009a)). These facts reflect that user-centered design becomes more and more prominent in this research area.

1.3. *Advancements to the State of the Art*

The main advancement to state of the art evaluation studies in HRI research is to address several evaluation factors and indicators in one evaluation study setting. Furthermore, the combination of an interdisciplinary method mix and investigating the societal impact of robotic systems in user studies with novice users are focussed in the evaluation approach presented in this deliverable.

2. Introduction

This deliverable presents eight evaluation studies conducted in order to gain insights about usability, social acceptance, user experience, and societal impact. Three of the evaluations were lab-based user studies, investigating the interaction of a user with a robot. The preliminary user study was conducted at the CNRS/LAAS JRL in Toulouse (France) with the HRP-2 robot. Another user study was conducted at the EPFL institute in Lausanne (Switzerland) with the HOAP-3 robot. The third user study took place at UC3M institute in Madrid (Spain), involving the remote control of the HOAP-3 robot. Furthermore two expert evaluation studies, both heuristic evaluations were conducted. The first heuristic evaluation aimed to evaluate the different robotic systems of the project partners in different interaction scenarios in terms of usability. The second heuristic evaluation was done in order to support the iterative design of a remote control developed by HP-EIC in order to operate different robots. Moreover, a focus group for getting insights about how tele-operated versus autonomous robots are perceived was conducted at PLUS in Salzburg. Two field trials with the ACE robot, mainly investigating the social acceptance of robots on public places, were performed in Munich together with TUM.

The basis for the indicators operationalizing, usability, social acceptance, user experience, and societal impact was the USUS evaluation framework. A detailed description of the USUS framework, describing the factor, indicators, methods, and the timeline can be found in D1.3@M6 and in Weiss *et al.* (2009).

These insights will form the basis for the final evaluation of the integrated scenario and thus also be a part of the final report on evaluation activities (D4.6@M36).

The present deliverable is organized as follows: After the Executive Summary and an Introduction given in chapter 1 and 2, methodological considerations and characteristics of

the conducted evaluations are discussed in chapter 3. Chapter 4 describes every study in detail, specifying the study setting, the instruments used, the procedure and the results. Chapter 5 deals with benchmarks-based evaluation which can be used in different applications and in different sectors. Insights gained on user acceptance, user experience, usability and societal impact are presented in chapters 6, 7, 8 and 9. Chapter 10 points out the lessons learned and recommendations for design gained in the user studies. Chapter 11 concludes the deliverable with a summary and outlook on future evaluation activities.

3. Methodological Considerations

A special characteristic of the evaluation in the Robot@CWE project is a broad spectrum of methods used which result from an interdisciplinary method mix. The main goal is to address as far as possible to address more than one evaluation factor in an evaluation study.

Table 1 gives an overview of the methods used for the evaluations as well as the factors addressed by the methods.

	Usability	Social Acceptance	User Experience	Societal Impact
Focus Group		X	X	
Heuristic Evaluation of different robots	X			
Heuristic Evaluation of remote control	X			
Preliminary User Study with HRP-2	X	X	X	X
User Study with Hoap3 (learning task)	X	X	X	X
User Study with Hoap3 (remote control task)	X	X	X	X
Preliminary Field Trial with ACE		X		
Follow-up Field Trial with ACE		X		
Expert interviews on societal impact				X

Table 1: Methods used and factors addressed

In the following definitions for the factors and methods used in the evaluation process are described in more detail.

3.1. Factor Definition

The factors and indicators assessed in the evaluation studies presented in this deliverable are based on the USUS evaluation framework (see Weiss *et al.* 2009 and D1.3@M6).

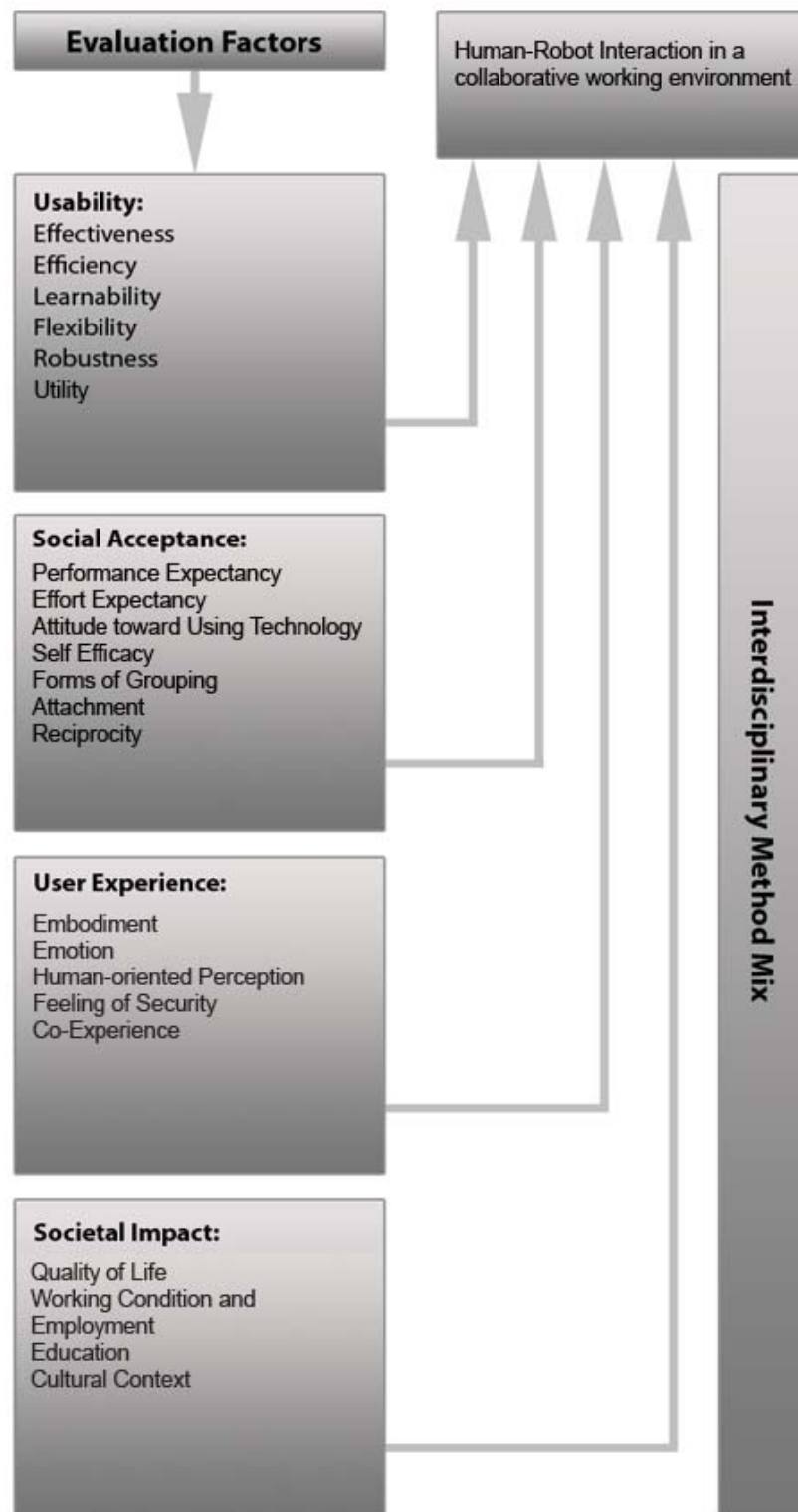


Figure 1 USUS Evaluation Framework

3.1.1 Definition of Usability:

The term usability can be defined as “the extent to which a product can be used by specified users to achieve effectiveness efficiency and satisfaction in a specified context of use” (ISO

9241-11 (1998)). The indicators for usability defined in the evaluation plan (D1.3@M6) were: effectiveness, efficiency, learnability, flexibility, robustness and utility.

3.1.2 Definition of User Experience:

Since this term is a very manifold concept in the field of HCI and research is still going on, the general definition from (Alben, 1996) of user experience can be applied into the field of HRI: “All the aspects of how people use an interactive product: the way it feels in their hands, how well they understand how it works, how they feel about it while they are using it, how well it serves their purposes, and how well it fits into the entire context in which they are using it”. The relevant indicators for user experience of socially situated robots defined in the evaluation plan (D1.3@M6) are embodiment, emotion, human-centered perception, feeling of security, and co-experience.

3.1.3 Definition of Social Acceptance:

User acceptance defined by Dillon (2001) is “*the demonstrable willingness within a user group to employ technology for the tasks it is designed to support*” For the evaluation studies presented in this deliverable social acceptance was defined as the “individuals’ willingness based on their interaction experiences to integrate a robot into an everyday environment”. Based on the UTAUT model (Venkatesh, 2001) and the object-centered sociality theory (Knorr-Cetina, 1998) the following indicators were defined for social acceptance: performance expectancy, effort expectancy, attitude towards using technology, self efficacy, forms of grouping, attachment, and reciprocity.

3.1.4 Definition of Societal Impact:

Societal impact can be defined as every effect of an activity on the social life of a community in general and more specific for the proposed framework: “Societal impact describes all effects the introduction of robotic agents consequences for the social life of a specific community (taking into account cultural differences) in terms of quality of life, working conditions and employment and education.”

3.2. *Description of Evaluation Methods*

3.2.1 Expert Evaluation: Heuristic Evaluation

A heuristic evaluation (HE) is a well-known method for finding usability problems in a given user interface (Nielsen, 1994). It involves evaluators who examine the interface with the purpose of identifying usability problems (Clarkson and Arkin, 2007). The method is quick, cheap and easy to apply and is applicable to a wide range of prototypes. A small set of evaluators (three to five) is sufficient to find about 75% of all existing usability problems (Nielsen, 1994). For identifying the usability problems a set of fundamental principles, so-called “heuristics”, are applied by the evaluators. Heuristics describe essential attributes that a system should provide in order to ensure that the user is able to perform a task within a specified context in an effective, efficient and satisfying way. During the evaluation session, each evaluator (most of the time an expert for the addressed domain) goes through the interface several times, inspects the various dialogue elements and compares them with the heuristics (Nielsen, 1994). Afterwards the lists of all evaluators are combined, resulting in a catalogue with the total list of usability problems. This list is given to the evaluators with the

instruction to rate the collected problems on their relevance (referred to as severity ranking). The final list of usability problems ranked with different severity can enable and foster the iterative development process of the system.

3.2.2 User Studies

The term “user study” does not address a single method but involves several methods for testing different HRI aspects such as usability, user experience, social acceptance or societal impact. With the help of a user study the experimenter is able to collect empirical evidence, whereas he/she can answer the research question or hypothesis postulated during the development of the experiment. User studies are based on tasks performed by the test subject, whereas the subject’s behavior is monitored and measured by the experimenter during the tasks. Additional metrics can be collected in order to measure the efficiency of a given system during the user study. Such metrics involve the task completion rate, the error rate and task duration. A further method often used in user studies is the “think aloud” method at which the test subject is asked to tell what he/she is actually thinking, looking, doing and feeling during the conduction of the test. This method helps the experimenter to get a first hand protocol of existing usability problems. Normally such user studies are video-taped and audio recorded as well since after the user study is over the experimenter can analyze the recorded material in detail. User studies offer a good opportunity in order to combine them with other methods like questionnaires or qualitative interviews. Such a user study can be conducted laboratory or field based which is explained below.

Laboratory based user study

A user study conducted in a laboratory offers a controlled environment where disturbing influences can be excluded. Furthermore a laboratory offers all the equipment needed during the test. A disadvantage of lab based testing is, the tested subject is not set in the environment the system one day will be placed and the test subject could feel a little lost.

Field Trial

The main characteristic of a field trial is that the evaluation does not take place in a laboratory but in the user’s environment, that means in a natural context and do not need to be task based. Furthermore, the procedure of such a user study is similar to a lab based user study but hereby the monitoring of the study works in a more passive way. Due to the fact of the possible appearing of unforeseen events it is often more unstructured. Through such influences it is often more difficult to analyze the data collected from the study.

Wizard of Oz Technique

User studies can be conducted with the help of the Wizard of Oz method, short WoZ. This technique allows simulating highly interactive systems. The origin of WoZ goes back to the testing of natural language systems, multimodal and (software-) agent based systems with real users (Kelly 1984). The WoZ technique offers to test a system at a very early stage of development, whereas a human controls the features of it, without telling the subject. So the system provides much more features as actually implemented and can respond to the actions of the user accurately as the system would do in the end. In the case of Human-Robot Interaction several advantages are included when conducting a user study integrating the WoZ technique. For example, better control about security and safety issues can be established while testing, simulation of important social cues and metrics like efficiency and effectiveness can be taken into account in a more comparable way. Nevertheless, disadvantages are

included if User Experience and Social Acceptance is evaluated: Is during the evaluation the perception of the robot measured or the perception of the human wizard?

Breaching Experiment

In field of social psychology a breaching experiment seeks to examine peoples' reactions to violations of commonly accepted social rules or norms (Garfinkel, 1967). Moreover, it disrupts ordinary action in order to “detect some expectancies that lend commonplace scenes their familiar, life-as-usual character, and to relate these to stable social structures of everyday activities” (Garfinkel, 1967). In a technical context a breaching experiment can give insights how novel technology possibly influences future society. This approach was used for the two field trials with the ACE robot.

3.2.3 Focus Group

A focus group can be defined as a “carefully planned series of discussions designed to obtain perceptions on a defined area of interest in a permissive, non-threatening environment (Krueger & Casey, 2000). The focus group method was originally designed as a marketing research tool and has been adapted for research in many fields, such as social sciences, but also in applied settings such as system development and evaluation. Focus groups are similar to group discussion. The features that set focus groups apart are:

- A clear plan for a controlled process and environment in which interactions among participants take place.
- The use of a structured process in order to collect and interpret data.
- Selected participants are based on characteristics they share, as opposed to differences among them.

It is important to note that a focus group only gathers qualitative data which can be used as input to further develop other research instruments which gather quantitative and generic results.

3.2.4 Questionnaires

Attrakdiff

The Attrakdiff is an instrument for measuring the attractiveness of interactive systems. With the help of pairs of opposite adjectives, users (or potential users) can indicate their perception of the system. It consists of 4 scales:

- Pragmatic Quality (PQ): Describes the usability of a product and indicates how successfully users are in achieving their goals using the product.
- Hedonic Quality - Stimulation (HQ-S): This dimension indicates to what extent the product can support needs in terms of novel, interesting, and stimulating functions, contents, and interaction- and presentation-styles.
- Hedonic Quality - Identity (HQ-I): Indicates to what extent the product allows the user to identify with it.
- Attractiveness (ATT): Describes a global value of the product based on the quality perception.

NARS

The “NARS” (Negative Attitude toward Robot Scale; Bartneck, 2005) is a psychological index in research on human-robot interaction. It is a standardized questionnaire which measures attitude factors like anxiety. The items range from 1 = absolutely agree to 5 = absolutely disagree. The NARS questionnaire consists of 14 questions regarding three subscales: „Negative Attitude toward Situations of the Interaction with robots“ (S1), „Negative Attitude toward Social Influence of Robots“ (S2), „Negative Attitude toward Emotions in Interaction with robots“ (S3).

SUS

The SUS (System Usability Scale) is a standardized (HCI) questionnaire addressing effectiveness, efficiency and satisfaction with a system (Brook, 1996). It consists of 10 items and yields a single number representing a composite measure of the overall usability of the system being studied. Scores for individual items are not meaningful on their own. The cumulative score is in a range between 0-100:

- 80-100: Users like the system
- 60-79: Users accept the system
- 0-59: Users do not like the system

It is important to mention that the SUS is no absolute ratio, but its interpretation depends on the experimental context.

PANAS

The Positive and Negative Affect Schedule (PANAS) is a 20-item self-report measure of positive and negative affect developed by Watson et al. (1988). It is measuring the positive and negative affect of directly after the interaction with a robotics system. PA and NA reflect dispositional dimensions, a high Negative Affect (NA) value indicated distress and non-pleasurable engagement. By contrast a high Positive Affect Value (PA) represents a pleasurable experiences engagement with the robot.

UX-Questionnaire

The user-experience questionnaire (subsequently called UX-Questionnaire) was developed by PLUS especially for assessing the indicators defined for the user experience evaluation factor: embodiment, emotion, human-centered perception, feeling of security, and co-experience. The questionnaire consists of 25 items (5 for each indicator). Participants rate the given statements from 1 “absolutely disagree” to 7 “absolutely agree”. The user experience indicators are calculated by summing up the ratings of the participants and dividing them by the item count. They rating of an indicator can thus get values from 1 to 7. The higher the value is, the more positively participants experienced the tested robot. The complete questionnaire can be found in Annex.

SoAc-Questionnaire

The social acceptance questionnaire (subsequently called SoAc-Questionnaire) was developed by PLUS especially for assessing the indicators defined for the social acceptance evaluation factor: performance expectancy, effort expectancy, attitude towards technology, self efficacy, attachment, forms of grouping, and feeling of reciprocity. To be close to the UTAUT model (for statistical analysis reasons) the factor facilitating conditions was added. Each of these 8

factors consists of 4 to 6 items, which are rated by participants on a scale from 1 “absolutely disagree” to 5 “absolutely agree”. The social acceptance indicators are calculated by summing up the ratings of the participants and dividing them by the item count. The higher the value is, the more positively participants assessed the social acceptance. The complete questionnaire can be found in Annex.

3.2.5 Interviews on Societal Impact

In order to find out how people imagine working and living together with robots in the future, experts and non-experts were interviewed. The results of these interviews will provide the basis for a standardized questionnaire about societal impact (the results of the questionnaire and the expert interviews will be presented in D4.6@M36).

Interviews (open questions) on Societal Impact for Non-Experts

The interviews with non-experts were conducted in combination with the lab-based user studies. The interview consisted of the following four main questions dealing with the participant’s expectations and imaginations what future society with robots could look like.

- Q1: In which way could robots be integrated into working life in future?
- Q2: How could life change if robots are integrated into a construction area?
- Q3: How will the usage of robots in the working context influence the future education system?
- Q4: How could you imagine that society will support the use of robots in the future?

Interviews with Experts

The expert interviews also consisted of four main topics, consistent with those mentioned for the user studies. These expert interviews were conducted with the two industry partners in the Robot@CWE consortium, SAS and DRAGADOS. A detailed analysis of the results of the interviews will be presented within D4.6@M36.

4. Evaluation Set-up

This section describes all user studies conducted in WP3. Each subsection consists of the partner involved, the study set up, the instruments used, the procedure and finally the results are described in detail.

4.1. Heuristic Evaluation of the Different Robotic Systems

The aim of the heuristic evaluation was to find and report usability problems of the robotic systems used in Robot@CWE. Following you will find a brief description of the evaluated robots:

- **RH-1** (provided by UC3M): This robot is able to perform tasks autonomously, like dynamic walking, object transportation, moving to the sound or the source of an image, etc, whereas at some tasks the interaction with the environment or humans will

be needed. For instance, lift a board, shaking hands with people, close/open a door, are just a few tasks the robot should be able to do¹

- **HRP-2** (provided by CNRS): This robot is the final version of the Human Robotics Project headed by the Manufacturing Science and Technology Center (MSTC), which is the direct successor of the HRP-2P. Hereby the robot has got some upgrades, like the ability to walk on uneven surfaces and some technical improvements.
- **HOAP-3** (provided by EPFL and UC3M): This robot has been designed in order to provide portability. The height of the robot is 60 cm and weights only 8.8 kg. The focus of the development of this robot was put on cooperation functions, like communication and image recognition. Further features are voice recognition and voice synthesis.

4.1.1 Study Setting

The development of the human-humanoid collaboration scenarios in the ROBOT@CWE project is conducted in four different countries. In order to evaluate each robot of the other research partner a video prototype evaluation was realized, which could reduce the effort of the evaluation to a minimum. In the evaluation ten experts in HRI with different research background took part and acted as expert evaluators, which granted a broader view on the problems. The material of the videos tapes was provided by each project partner. The tapes featured recordings of the robots RH1, HRP-2 and HOAP-3 from the project partner and were used for the expert evaluation. The overall research question was: “Which major usability problems occur in the interaction with the robot?”

4.1.2 Instruments

The evaluation of the video-taped human-robot collaboration scenarios was based on the heuristics from Clarksen and Arkin (2007), which are shown in Table 2.

1. Sufficient information design
2. Visibility of system status
3. Appropriate information presentation
4. Use natural cues
5. Synthesis of system and interface
6. Help users recognize, diagnose and recover from errors
7. Flexibility of interaction architecture
8. Aesthetic and minimalist design

Table 2: Heuristics of Clarksen and Arkin 2007

In order to reach a common ground between the expert evaluators a manual explaining the method, was sent to the expert evaluators. The manual consisted of a general introduction of the method, the procedure of the evaluation and the severity rating by Nielsen (1994) whereas the severity of a usability problem is a combination of three factors:

- The frequency with which the problem occurs: Is it common or rare?
- The impact of the problem if it occurs: Will it be easy or difficult for the users to overcome?

¹ This robot was only assessed within the heuristic evaluation

- The persistence of the problem: Is it a one-time problem that users can overcome once they know about it or will users repeatedly be bothered by the problem?

The following 0 to 4 rating scale was used to rate the severity of usability problems:

- 0 = I don't agree that this is a usability problem at all
- 1 = Cosmetic problem only: need not be fixed unless extra time is available on project
- 2 = Minor usability problem: fixing this should be given low priority
- 3 = Major usability problem: important to fix, so should be given high priority
- 4 = Usability catastrophe: imperative to fix this before product can be released

Furthermore templates, see Table 3: Template in order to describe the identified usability problem, for the problem lists were provided as well as hints and literature references.


Scenario	Collaboration: Raising Object
Problem Number	1
Problem Title	Missing Feedback
Detailed Problem Description	The human does not receive any understandable feedback when the robot notices the object, which should be carried together. Therefore the human does not start the task although the robot is ready to do so.
Heuristic violated by the problem	Visibility of system status
Video time stamp of the detected problem	

Table 3: Template in order to describe the identified usability problem

4.1.3 Procedure

Each of the project partners provided a video-taped interaction scenario. The project partners (expert evaluators) were asked to first describe the scenario, e.g. the robot and the human try to raise an object together. Therefore 39 different usability problems were found in 6 different collaboration scenarios, shown in Table 4.

Task	Robot	Problem (N)
Collaborative tele-manipulation: move an object	HRP-2	12
Collaborative manipulation of an object	HRP-2	3
Collaborative manipulation of an object by tele-operation	HRP-2	3
Manipulation of an object by teleoperation	HRP-2	2
Teaching new manipulation skills to a humanoid robot	HOAP-3 HRP-2	5

Collaborative ladder transport	HR1 Simulation	14
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Table 4: Categories of the task tested in the evaluation; problems per robot (N)

The expert evaluators were asked to identify, according to the heuristics of Clarksen and Arkin (2007), usability problems and write them down on the provided template, see description in chapter 4.1.2). The next step of the evaluation process was to collect these templates from the project partners and create a complete list of found usability problems. The new list was sent to the project partner by random distribution, in order to avoid effects to their position. Then the identified usability problems were rated using the severity. The last step of the evaluation was to collect the problem list from each project partner sent before and put the severity ranking together.

4.1.4 Overview of Results

The expert evaluators could identify usability problems violating seven out of eight heuristics. Table 5: Violated heuristics gives an overview of the violated heuristics and how often each of it was violated.

Heuristic		Number of violations	Mean of the severity ranking
1	Sufficient information design	6	2.40
2	Visibility of system status	13	2.42
3	Appropriate information presentation	9	2.61
4	Use natural cues	7	2.31
5	Synthesis of system and interface	7	2.44
6	Help users recognize, diagnose and recover from errors	7	2.67
7	Flexibility of interaction architecture	10	2.55
8	Aesthetic and minimalist design	0	0
Total		59	2.49

Table 5: Violated heuristics

All in all, 59 heuristics were violated, whereas heuristic 2, 3, and 7 covered over 50% of the found usability problems. Furthermore, Table 5: Violated heuristics shows that the difference between the violated heuristics is not significant but the number of violations of each heuristic can show the weakness of the system. Briefly said, the problems of such robotic systems lie in the lack of the provided feedback, the communication and the availability of the information coming from the robot. The developed guidelines (Clarksen and Arkin, 2007) and the provided video material could show the essential usability problems caused by the robotic systems. In order to get better results it would be recommended to use more than five expert evaluators as proposed by Clarksen and Arkin (2007) due to the fact that the expertise of the expert evaluators could be used in a broader context.

4.2. Focus Group with HRP-2: Autonomous vs Tele-operated

The aim of the focus group study was to investigate if a collaborative task with the HRP-2 robot is differently perceived by people depending if they think that the robot is tele-operated

or autonomously moving. We wanted to gain qualitative insights on the indicators for user experience and social acceptance.

4.2.1 Study Setting

The two focus groups took place at the ICT&S Center in Salzburg (PLUS) on the 6th and 7th of February 2008. Each focus group contained 9 participants. It was decided to choose an odd number of participants in order to get clear majority answers (The participants were mixed in sex and age: Every group was composed of 5 males and 4 females. The mean age of group I was 29.78 years (mean = 29.78, S.D. = 8.10), ranging from 22 to 43 years, and the mean age of group II was 31.67 years (mean = 31.67, S.D. = 9.05), ranging from 24 to 53 years. The duration of one focus group was about 2.5 hours and the whole procedure was recorded on video tape. Participants were told to take place on one of the seats around the table and invited to take soft drinks and snacks located on the table. There was one moderator and one assistant journalizing the discussion and supporting the moderator.

The following research question was addressed: “Are autonomous robots differently perceived than tele-operated robots in collaborative working environments, when focusing on social acceptance, and user experience?” The outcome of these methods is qualitative data which should provide information about attitudes and feelings of the participants and ideas for design implications.

4.2.2 Instruments

In each focus group, the participants were handed out three questionnaires: a basic questionnaire for demographic data as well as usage of media and questions about robotics, the NARS questionnaire and the AttraktDiff questionnaire. What is more, a “robot-building-set”, containing the most important parts (feet, arms, head, torso) of a robot in three different variations (functional, human-like and animal-like) was provided. Each group was presented a video showing a robot collaborating with a human; group I was presented a video (approximately three minutes long) showing a tele-operated robot, whereas group II was shown an autonomous robot. The two videos were roughly the same (same robot and collaboration human), however, for group II the scenes showing a tele-operating human were left out and the participants were told that the robot would operate autonomously.

4.2.3 Procedure

After welcoming the participants and explaining the procedure, the participants had to fill out a questionnaire about demographic data and the NARS questionnaire. After that, room lights were switched off and a video showing a robot (depending on the condition either tele-operated or autonomous) working together with a human was presented. Immediately after watching the video, the robot shown in the video had to be rated by completing the AttraktDiff questionnaire. Next, the discussion was opened by a “warming up exercise” - every participant shortly introduced himself and explained what the term “robot” means for him. After that, the first task was to write down terms and ideas associated with the video on small sheets of paper and stick them up on a flip chart.

Then, a group discussion about humans working together with robots was carried out, involving the following topics: Co-experience (Collaboration), feeling of security (trust, safety), emotion and embodiment (all factors for user experience) as well as self efficacy, forms of grouping, reciprocity and attitude towards using technology (all factors for social acceptance). At the end of the session, participants had to design a robot which in their opinion was best suited to the task shown in the video together. In order to design the robot, they were provided the “robot-building-set” (feet, arms, head and torso) which they should put together as they wanted to.

4.2.4 Overview of Results

Attitude towards Robotics

Most of the participants indicated to have big or very big interest in technology (group I: 5, group II: 6); nobody of the two groups showed no interest in technology at all. Concerning interest for robotics, most participants told to be moderately interested in (group I: 4, group II: 3). Moreover, most participants indicated to be neutrally attuned toward robotics, as positive or negative implications of robotics depend on the use of it (group I: 6, group II: 6). The subjects also declared that they could imagine living together with robots which could accomplish exhausting tasks for them (group I: 8, group II: 6). Concerning happiness, most participants indicated that robots cannot contribute to that (group I: 5, group II: 5). However, most subjects indicated that robots can accomplish for the well-being of individuals (group I: 8, group II: 5).

NARS

The NARS was foremost used in order to identify possible differences between the two focus groups concerning attitudes towards robots. In order to test for differences, a t-test for independent samples was carried out. The results indicated that there was no significant difference between the two groups ($p > 0.001$) on all three subscales.

Assessing negative attitude toward situations of interaction with robots (subscale 1), subjects reported to *disagree* (mean = 2.18, S.D. = 0.78) with the corresponding statements. Overall, participants do not have a negative attitude toward situations of interaction with robots. Concerning negative attitude toward social influence of robots (subscale 2), subjects indicated to be *undecided* (mean = 3.15, S.D. = 0.62) about the given statements. Therefore, participants do not show a clear tendency toward a positive or negative attitude concerning the social influence of robots.

Assessing negative attitude toward emotions in interaction with robots (subscale 3), participants also reported to be *undecided* (mean = 3.26, S.D. = 0.75) about the given statements. This indicates that participants do not have an explicit positive or negative attitude concerning emotions in the interaction with robots. These results show that both groups have the same attitudes toward robots in general and that these attitudes are not significantly negative.

AttrakDiff

In our study, the AttrakDiff was used in order to evaluate the robot presented in the video with regard to the three dimensions mentioned above. In other words, we wanted to find out if the tele-operated robot was differently evaluated than the autonomous one.

All in all, the tele-operated robot was better rated than the autonomous robot in all three dimensions. Concerning the pragmatic quality, this means that the usability and the success for users in achieving their goals using the tele-operated robot are higher compared with using the autonomous robot. Regarding hedonic quality, the participants can better identify with the tele-operated robot and feel more supported in their needs for interaction- and presentation-styles. The attractiveness of the tele-operated robot is also higher rated, meaning that participants evaluate the quality of the tele-operated robot better. These differences, however, are statistically not significant, which can be explained by the small sample size. Overall, the tele-operated robot seems to be perceived more positively in contrast to the autonomous robot.

Focus Group Discussion

Overall, the answers of the two groups during the discussion were remarkably consistent, with one exception: Group I (tele-operated robot) stated out that there would be no difference for them if the robot would be autonomous or tele-operated, whereas group II (autonomous robot) reported that they would prefer working together with a tele-operated robot. For the questions addressed within the focus groups, see the discussion guideline in Annex A.

Collaboration with robots

Generally, the participants associated positive expectations as well as negative expectations and fear about the future when working together with robots. Some of the mostly mentioned arguments concerning collaboration are that robots will never be able to substitute colleagues at work, as humans are needed for good social contact (working together with robots increases isolation loneliness of human beings. For example, participants quoted: “*It needs human beings for good social contact*” or “*A robot shall not substitute a human being.*” Most of the participants agree that a robot will never be an equal working colleague for them; one participant mentions: “*I cannot imagine a robot to be an equal working colleague, and not more than ever as supervisor*”. All participants agree that a robot should displace a human being only in case of monotonous or dangerous work (for example: “*I think it is an advantage when robots do dangerous work*”). Robots should only adopt physical work and support humans. What is more, they think that a social robot would not be accepted because that would compete (Konkurrenz machen) with humans (robot would be equal or better).

Fear of robots

The participants seem not to be afraid that robots could one day substitute human beings – they see robots as another technical development which can be used positive as well as negative (“The person who invented electric current never intended bad things like electrocution; you can always apply new technological applications in a positive or in a negative way.”) . However, they are afraid of lacking human communication and interpersonal relationships due to robots. What is more, they fear that a very humanoid robot (which has emotions) leads to emotional attachment towards the robot (which is not good in their opinion). One participant quoted: “Robots convey isolation, also in the job”.

Difference between autonomous and tele-operated robots

In the first group (presentation of tele-operated robot), participants indicated that there would be no difference if the robot was tele-operated or autonomous. For example, one participant

said: *“I see here no difference, the important thing for me are the security procedures”*. The only advantage of remote-controlled robots would be that the human can interfere in cases of accidents (but only in cases of human failures). One person mentioned: *“When the system breaks down, remote-control is important because the human can control the situation”* (in opposite to situations where the robot acts autonomously). Participants of group II indicate that they feel more secure with remote-controlled robots because a human has control; one participant indicated: *“With remote-controlled robots, I feel more secure because you can control them”*. The whole group agrees that they would prefer a remote-controlled robot (they think that the abilities of a robot are limited). Another point would be that participants think that they can appreciate the behavior and thinking processes of humans, whereas they cannot predict the behavior and thinking processes of a robot (*“as a human you can appraise humans whereas you have no insight into robots”*).

Security

Participants tend to feel more secure working together with a tele-operated robot (compared with an autonomous robot). They know that, from a statistic point of view, machines make fewer failures than humans. However, they indicate that they feel intuitively more secure when a human is the operator (tele-operated robot). One participant argues: *“I know that statistics say something else, however, I feel more secure with humans”*. Some participants indicate that robots are something you can get used to, similarly to telephones or computers some decades ago. They think that the fear of new developments and technologies is human.

Competence

Autonomous robots should be deployed for monotonous work (*“autonomous robots are reasonable for 08/15 workings”*); remote controlled robots should be used for workings in medicine, for mitigation of bombs or when working with toxic materials (because the human can react to the situation). As the robot is not able to consider all possible situations, a human is needed for “back-up” (especially under exceptional conditions and when quick reaction is needed).

Previous knowledge for interacting with robots

Most participants think that school enrolment for working together with robots is necessary (the human has to know what the robot is able to do).

Embodiment

Participants indicate that concerning the appearance of the robot, the most important aspect is functionality. One participant quotes: *“A robot should be functional and not human”*. Another participant indicates: *“It should be clear for a human that it is about a robot”*. Participants think that the robot presented in the video looks like a human because designers think that if a robot looks like a human being, the acceptance of the robot is higher.

Fields of application for robots

All in all, participants think that robots should mainly take over work that has adverse health effects, is dangerous or monotonous.

Social behaviour of robots

Most participants think that a robot is only a technical device and therefore cannot act socially. However, a human could behave socially towards a robot (but not the other way

round). One participant indicates: “*You can develop a social relationship to a technical device, but not the other way round: the technical device cannot establish a social relation to the human*”.

Design of the robot (Embodiment)

The participants think that the robot should be functional and not humanoid, so that it is clear that it is a robot. What is more, a participant indicates that human-like robots would exert pressure or would be threatening (“*the more human-like, the more threatening*”). Because of this, the participants decide to build a robot (which should substitute the robot in the presented video) which has no head but only one arm for grasping. In other words the participants focus on functional aspects of the robot which are necessary for performing certain tasks.

4.3. Preliminary User Study with HRP-2: Whole Body Motion Task

Within the preliminary user study with HRP-2 the following research questions were investigated.

- How do novice users experience the collaboration with the humanoid robot HRP-2 when interacting via speech commands?
- How do users perceive the system in terms of usability?
- Does the general attitude towards robotics change because of the interaction with the robot?
- How do people imagine the future society after interacting with the robot?

The results of this user study can also be found in Weiss et al. (2009a).

4.3.1 Study Setting

The preliminary user study with HRP-2 took place at the LAAS institute (CNRS) in Toulouse, France from 8th to 11th of July. The study was conducted with 4 participants (1 female, 3 males). The youngest participant was aged 23, the oldest one 39, with an average age of 27.5 years. All participants indicated to use the internet for private purpose daily and to read or write e-mails every day. All four participants use the computer (PC or notebook) every day. Two of the participants watch TV every day, one several times a week and one about one time in a week.

4.3.2 Instruments

The participants had to accomplish two tasks which were based on speech recognition and on interaction with the HRP-2 robot. Their performance and behavior was observed and recorded on video tape and thus analyzed at a later point. Additionally, the participants had to accomplish four questionnaires: the Attrakdiff, the NARS, the SUS and a self developed questionnaire based on 25 items related to the factors emotion, co-experience, feeling of security, human-oriented perception and embodiment. Finally, interviews with the participants about societal impact were conducted.

4.3.3 Procedure

The participants had to accomplish two tasks which were based on speech recognition (see below). In task 1, the participant’s job was to tell the robot to pick up the ball; in task 2, the

participant’s job was to tell the robot to put the ball on the table (for details, see Table 6). Therefore, participants had to imagine the following scenario:

“Imagine you are working at construction area and need a special tool. A humanoid robot, its name is fourteen, is supporting you by providing with your needed tools. You can control the robot with your needed tools. You can control the robot with predefined commands; therefore it picks-up and transports the tool”.

Task 1	Task 2
Instruction: <i>“Tell the robot to pick up the orange ball. Therefore, you have to use the following commands (after each command, wait for the reaction/answer of the robot, before you start with the next one)”</i>	Instruction: <i>“Your task is now to tell the robot to put the orange ball on the table. Therefore, you have the following commands”</i>
Commands needed: <ul style="list-style-type: none"> - <i>“14” (is the general command which activates the robot)</i> - <i>“Go to the green box”</i> - <i>“Look down”</i> - <i>“Take the orange ball”</i> 	Commands needed: <ul style="list-style-type: none"> - <i>“14” (is the general command which activates the robot)</i> - <i>“Turn to the left”</i> - <i>“Go to the yellow table”</i> - <i>“Look down”</i> - <i>“Put the orange ball on the yellow table”</i>
Additional commands: <ul style="list-style-type: none"> - <i>Turn to the left</i> - <i>Turn to the right</i> 	Additional commands: <ul style="list-style-type: none"> - <i>Turn to the left</i> - <i>Turn to the right</i>

Table 6: Instructions and Commands used for Task 1 and Task 2.



Figure 2 Interaction with the HRP-2 robot

4.3.4 Overview of Results

Usability

	Task 1 (“tell the robot to pick up the ball”)	Task 2 (“tell the robot to put the ball on the table”)
Solved successfully	2	3
Solved with help	2	1
Not solved	0	0
Average rating of difficulty²	1.5	1.33
Average task duration	3:53	4:55

Table 7: Results from task 1 and 2.

Participants liked (answer count)	Participants disliked (answer count)
Robot answered in an nice way (1)	speed of the robots reaction (4) (too slow)
No need of additional and repeated commands (1)	TP felt insecure if the robot is close enough to grasp the ball and therefore already had to look on how to proceed with the next command. (1)
Robot describes all moves very good and helpful (1)	There was orange and purple misunderstanding (1)
Impressed, really impressed, if it was doing something wrong it was my fault (1)	I did not understand what it said, I had just to give commands (1)
Amazing, like in a movie (1)	Not every move needs a command (1)
The fears the robot would not understand me, were not realized.	When it still needs human it is not useful (1)
Feeling very close to the process (1)	

Table 8: Results from thinking aloud during task 1.

Participants liked (answer count)	Participants disliked (answer count)
Easy to use (2)	Difficult: I had to figure out and understand how it works in term machine (1)
I thought I need to talk slow, I would not have thought it is so precise (1)	I saw the robot as a machine, not an human (1)
Cool and easy to do (1)	The robot is not human like, I do not remember that the robot detected my face (1)
I was comfortable when the robot explained why he did not do the command (1)	Comprehension should be better (orange-purple) (1)
	I thought he will remind the yellow table that would be more logical (1)
	It should remind things then it gets easier (1)
	I was a little bit stressed as it did not understand the first command.
	Its movement is slow (1)

² from 1 “very easy” to 5 “very difficult”

	The time between answer and movement is too long (1)
	Improve: having different programs, one for talking, one for movement (1)
	Lack of pronunciation (p of put, and p of purple)

Table 9: Results from thinking aloud during task 2.

Perceived Usability of the Robot

The SUS revealed a cumulative score of 78.8 for HRP-2. This means that users accept the system. However, the experimental context, in this case the evaluation of the speech interaction with the robot has to be taken into account.

User Experience

Attrakdiff: The comparison of the mean values for each scale shows that people experienced the robot rather heterogeneously, especially the factor HQS. For the other factors (PQ, HQL, ATT) is general room for improvement (see Figure 3).

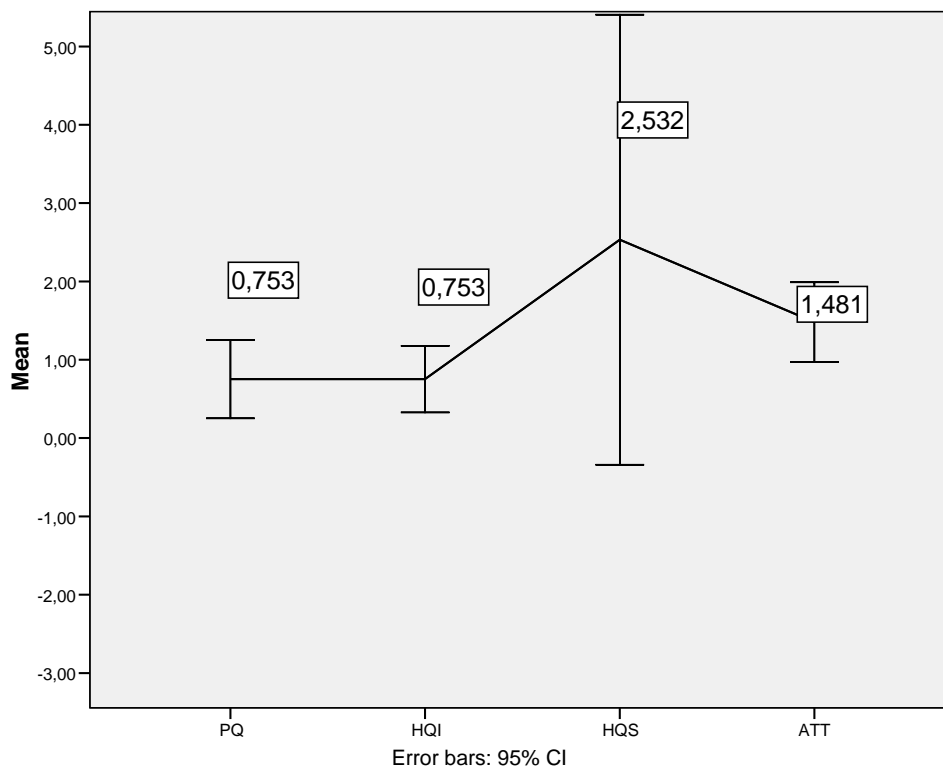


Figure 3: Attrakdiff diagram

UX-Questionnaire: The interaction with the robot is experienced positively in terms of emotion in specific, as the high average value of the indicator emotion (mean: 5.85, S.E. 0.3) indicates. Participants had fun during the interaction with the robot and were not disappointed or angry if the robot did not understand a command. Also embodiment (mean: 5.33, S.E.0.47), feeling of security (mean: 4.93, S.E. 0.47) and human-oriented perception (mean:

5.2, S.E. 0.38) reach quite good values. Only located in the middle of the field is the indicators co-experience, with an average value of 3.7 (S.E. 0.25). Take a look at the diagram of Figure 4.

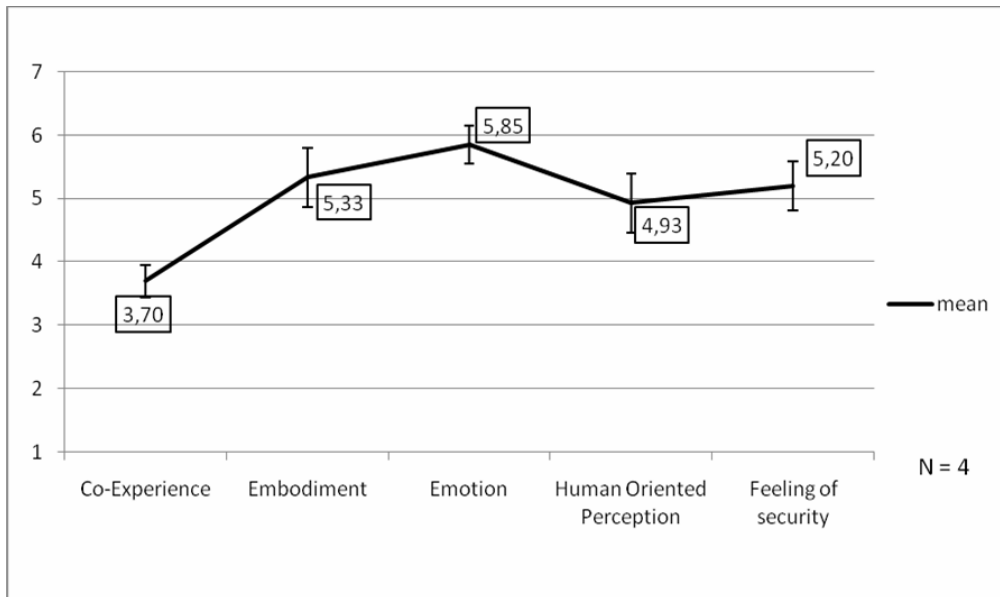


Figure 4 UX-questionnaire indicator diagram

Attitude towards Robotics

NARS: There is a significant difference between the rating of “negative attitude toward situations of the interactions with robots” (S 1) before and after the test. After the experiment/test the rating of the “negative attitude toward situations of the interactions with robots” is significantly (.009) lower than before the experiment. Also the rating of “Negative Attitude toward Social Influence of Robots” (S 2) has significantly changed. Before the test the rating of “Negative Attitude toward Social Influence of Robots” has been significantly higher (.041) than after the test. The rating of “Negative Attitude toward Emotions in Interaction with robots” (S 3) has also decreased, but not significantly.

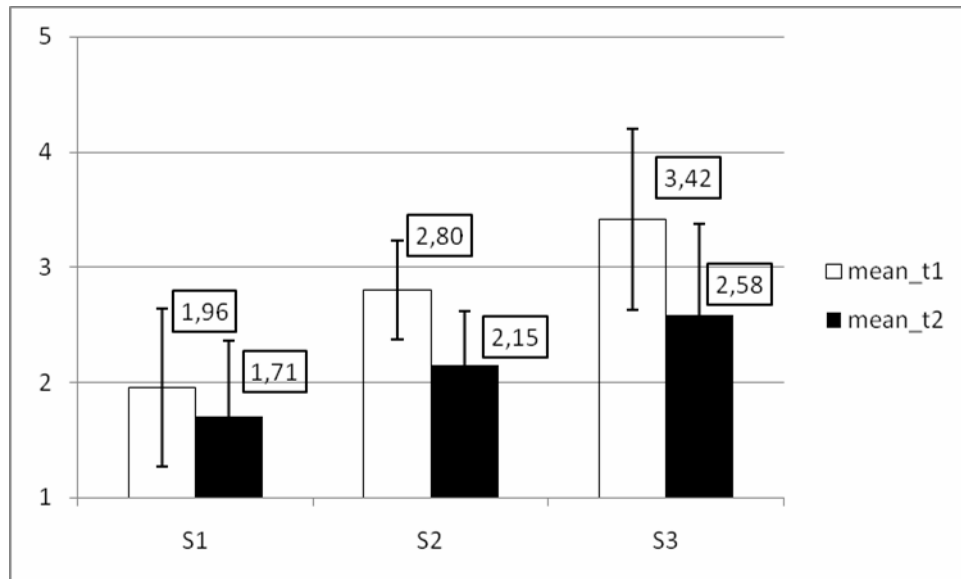


Figure 5 NARS diagram

Societal Impact Interview

When discussing about the question “in which way could robots be integrated into the working life in future”, 3 of 4 participants use the term “replacement”, which implicates that if robots are integrated into working life, automatically something or someone other is excluded from work (e.g. humans, machines). Therefore “replacement” is a negative term. Basically the participants are of the opinion that robots can replace on the one hand “slavery work” and on the other hand dangerous work. The term “slavery work” is defined as both repetitive tasks in construction factories and domestic work like cleaning, cooking, washing the dishes, cutting the grass or even driving a car. As examples for dangerous work the participants name “finding lost people in the mountains” or “lifting heavy things”. In the participants` opinion the advantage of using robots is that they can be replaced when they are broken, the disadvantage is that human life is nowadays cheaper than robots (e.g. in China). The following citations show that the participants are thinking differently about the integration of robots into the working life.

- *“It is impressive, but dangerous, we are a human society not a robot society, we have to keep humanity”*
- *“Environments working harmful for humans”*
- *“Robots are useful as assistance”*
- *“You can replace a robots if it is broken”*

Two participants foreground the dangers aroused through the integration of robots into working life (e.g. unemployment), the other two participants do not mention dangers but give priorities to the advantages that could accrue by the usage of robots in the working life. So half of the participants vision the integration of robots into the working life more positively, half of the participants negatively.

Concerning the question how life could change if robots are integrated into a construction area, the participants forecast both positive and negative effects. One negative effect is the

unemployment as a result of the replacement of human by robots. Also negatively seen is the competition between robots and human. The participants are of the opinion that robots will compete because they do not need to eat or drink and therefore are more reliable which means that the participants think that the costs of the workers are the most crucial employment-factor. Positively is seen that there will be less accidents in future working life with robots, so work will be more saver, there will be less health problems and people will have more spare time where they have the possibility to do funny things while robots are doing their work (e.g. their household). Furthermore participants expect that work that only can be done by human will be more valued in a working life future with robots.

Conclusion: Participants think there will be more unemployed people, because robots are doing their work. At the same time people will have more time for doing funny things. What participants did not think of is the inconsistency between increasing unemployment and increasing fun in the spare time. There will be probably increasing fun for one group of people and less fun for the other unemployed group that cannot afford robots for domestic work.

About the question how usage of robots in the working context will influence the future education system, participants have two different concepts. One part of participants is of the opinion that people have to learn the usage of robots in school (e.g. school subject “technology” beginning at the age of about 15). The other part of participants thinks that children will be able to learn outside school how to use robots (e.g. “parents will teach the children the dangers of robots, it is like with cars”). Therefore, we can distinguish between two robots-education-types:

- Type 1: A robot is only one more technology, and there is no need for special education. Computers in education are enough.
- Type 2: There should be an introduction of robots in school, so people get to know how to interact with a robot.

The last question was on how the society would support the use of robots in the future. For participants the usage of robots in future is mostly a benefit-cost-question. They think it depends on the price, the tasks the robot is able to do, the duration it is fulfilling the tasks and so on. But also the ease of use and the main aim will be important factors. (If robots are only dedicated to economic growth they will not be as accepted as if robots are dedicated to our life). Participants are of the opinion if people get used to robots (if they are comfortable), they will be just another technology, like cars. For the young generation robots could be domestics, like computers, especially if they get cheaper and quicker.

4.4. *User Study with Hoap3: Learning Task*³

Within the first user study with HOAP-3 the following research questions were investigated:

- How do novice users experience the collaboration with the humanoid robot HOAP when interacting via speech commands and via demonstrating specific motions?

³ The user study with HOAP-3 in Lausanne is currently submitted as: Weiss, A., Igelsböck, J., Calinon S. Billard, A., Tscheligi, M., *Teaching a Humanoid: A User Study with HOAP-3 on Learning by Demonstration*, IEEE Ro-Man 2009, Toyama, Japan.

- How do users perceive the system in terms of usability?
- Does the general attitude towards robotics change because of the interaction with the robot?
- How do people imagine a future society with humanoid robots as co-workers, after interacting with the robot?

4.4.1 Study Setting

The user study with HOAP-3 took place at the LASA institute (EPFL) in Lausanne, Switzerland from 10th to 15th of August. 12 participants (8 females, 4 males) took part in the study. The average age of the participants was 26.58 years; the youngest participant was aged 16, the oldest participant was aged 40. More than half of the participants (7 out of 12) use the PC every day, two of them only once a week or less. Most of the participants (10 out of 12) use internet at work every day. For private purposes, most of the participants (10 out of 12) use internet at least several times a week. Moreover, every participant owns at minimum one mobile phone and all participants except of one have at least one notebook in their household.

4.4.2 Instruments

In order to find out more about human-robot interaction, participants had to accomplish two tasks based on demonstration of specific motions (see 4.3.3). The tasks were video-taped and accompanied by a retrospective think aloud. Moreover, 6 questionnaires had to be filled in: the AttrakDiff, the NARS, the SUS, the PANAS, the UX-questionnaire and the SoAc-questionnaire. At last, interviews about societal impact were taken.

4.4.3 Procedure

Two tasks which were based on demonstration of specific motions had to be conducted. In task 1, the participants had to teach the robot to push this box away from its working space into their direction; in task 2, the participant's job was to teach the robot to close this box by its own (for details, see Table 10). To prevent a learning effect from one task to the other, the order of the tasks was counter-balanced, so that in condition 0 task 2 had to be accomplished first, and in condition 1, task1 was the first to be accomplished.



Figure 6 Learning task with HOAP-3

Before starting with the task, the following scenario was described by the instructor: “Imagine you are working at an assembly line in a big fabrication plant. A new robot is introduced, which should support you in solving tasks. You can teach the robot specific motions by demonstrating them (meaning move the robot’s arm like you expect it to move it later on its own); the robot will repeat the learnt motion. You can repeat this “demonstration-repetition-cycle” as long until you are pleased with the result.”

Task 1	Task 2
<p>Instruction: <i>This task is to teach the robot to push this box away from its working space into your direction.</i></p> <p><i>The task is split up into the following action sequences:</i></p> <ol style="list-style-type: none"> <i>1. Show the robots the specific task card by putting it on the table</i> <i>2. Demonstrate the robot to push the box with its right arm, by putting the box very</i> <i>3. Let the robot repeat what it learnt.</i> <i>4. If necessary repeat sequences 2 and 3 until you are pleased with the way the robot pushes the box</i> <p><i>The interaction with the robot is based on speech commands. Just follow the commands of the robot and answer to it with yes or no (or any other answer proposed by the robot)</i></p>	<p>Instruction: <i>This task is to teach the robot to close this box by its own.</i></p> <p><i>The task is split up into the following action sequences:</i></p> <ol style="list-style-type: none"> <i>1. Show the robots the specific task card by putting it on the table</i> <i>2. Demonstrate the robot to close the box with its right arm, by putting the box very close in front of the robot and moving its arm.</i> <i>3. Let the robot repeat what it learnt.</i> <i>4. If necessary repeat sequences 2 and 3 until you are pleased with the way the robot closes the box</i> <p><i>The interaction with the robot is based on speech commands. Just follow the commands of the robot and answer to it with yes or no (or any other answer proposed by the robot)</i></p>
<p>Start: First HOAP-sentence</p> <p>End: participant says: “I am pleased with the task”</p>	<p>Start: First HOAP-sentence</p> <p>End: participant says: “I am pleased with the task”</p>

Table 10: Instructions and Commands used for Task 1 and Task 2.

4.4.4 Overview of Results

Usability

TP	total dur.	Task compl.	demo count	satisfied demos	repetition count	final satis.
1	2:52	Yes	3	0	2	no
2	2:49	Yes	2	1	2	yes
3	10:14	No	4	1	4	no
4	1:59	Yes	1	1	2	yes

5	5:02	Yes	5	2	2	yes
6	3:04	Yes	3	1	1	yes
7	5:28	Yes	4	3	3	yes
8	3:46	Yes	4	1	1	yes
9	5:30	Yes	5	4	4	yes
10	2:44	Yes	1	1	2	yes
11	2:24	Yes	1	1	2	yes
12	10:45	Yes	11	7	12	yes

Table 11: Close the Box

Average rating of difficulty (from 1 very easy to 5 very difficult):

- Average rating of task “Close the box” = 2.5

TP	total dur.	task compl.	demo count	satisfied demos	repetition count	final satis.
1	4:05	Yes	3	3	3	no
2	3:56	Yes	2	2	2	yes
3	1:55	yes	1	1	2	yes
4	2:57	yes	2	1	2	yes
5	2:49	yes	2	1	3	yes
6	1:38	yes	1	1	1	yes
7	4:02	yes	3	2	2	yes
8	3:27	yes	2	2	3	yes
9	2:19	yes	2	1	1	yes
10	6:35	yes	5	5	5	yes
11	4:01	yes	4	4	4	yes
12	6:01	no	8	4	4	no

Table 12: Push the Box

Average rating of difficulty (from 1 very easy to 5 very difficult):

- Average rating of task “Push the box = 3.25

Participants liked (answer count):	Participants disliked (answer count):	Participants liked to improve (answer count):
<ul style="list-style-type: none"> • the robot is useful, it will be helpful • I felt pleasure on the demonstration • funny, simple (2) • great feeling during the demonstration • teaching of the arm was impressing 	<ul style="list-style-type: none"> • I did not understand where its range of vision is (2) • The robot could not move arm and shoulder enough • I did not understand what the robot wants • The height of the box does not correspond with 	<ul style="list-style-type: none"> • Mark the place where the box should stand (3) • Make the ability of the arm more flexible • With training it would be easier, I was not used to it • The arm should have one more degree of freedom

<ul style="list-style-type: none"> • there is nothing I did not like (2) • I was surprised that the robot did so quickly and well • it was easy to adjust its arm • it would be easy to work with him • he is like a human and has a sense of humour • the action was easier, more comfortable to make (2nd task) • the eyes shine beautifully, but a more pastel colour was better • the robots voice is comfortable • he is a robot as one imagines • the robot was easy to teach 	<p>the length of the arm</p> <ul style="list-style-type: none"> • I did not understand why he did not see the card • I was frustrated because I could not explain the robot • Confused what the robot said, robot does not expect an answer • I was afraid the robot could get stuck • I did not see the pushing distance • uncontrollable power • The thing behind the fingers commoves • It was annoying that he did not learn the movements • It should produce more precisely the angle of the motion • I could not estimate how it will do the task at the end 	<ul style="list-style-type: none"> • If I touch the box it should stop moving its arm • The movements should be accelerated for pushing • I wanted to say stop, I have to say start but not stop • Range of the arm, shape of the hand • Talk less, because confusing • I wish he could see where the box should stand (variable zero point)
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Table 13: Results from thinking aloud during task 1.

Participants liked (answer count):	Participants disliked (answer count):	Participants liked to improve (answer count):
<ul style="list-style-type: none"> • easy because quite natural teaching (you really could move the object) • feeling comfortable • human voice • oh it has five fingers(participant smiles) • it really reproduced the motion exactly • easy to understand him • nice voice, not scary like in the movies • it is fun • technically easy • congenial robot, obedient, ready to learn, likes to talk and likes 	<ul style="list-style-type: none"> • the robot talks a lot • I did not know how to put the box • low range • communication has close boundaries • it would have been easier to move the left arm • a bit frustrating • main difficulty: few movement possibilities • every time the robots arm was in a different position, so I had to change the position of the box too. • Difficult to get used to the force of the robot (2) 	<ul style="list-style-type: none"> • Make the arm more accessible • A starting position for the arm of the robot would be helpful • Fix the standpoint of the box • It would be helpful if he explained where he can see • The capabilities of its hand should be used more (also the fingers) • Instruction of the robot, the “start” thing is confusing • If the robot likes to learn how to close the box, he

<p>feedback</p> <ul style="list-style-type: none"> • advanced abilities of the robot • object adaption • looks human • funny • he did what I wanted him to do, I was satisfied • I would not change anything (2) • I think the robot is clever • the robot is very useful • surprised by the red eyes, how smooth it worked and how easy to move • more easy than the other task (2) 	<ul style="list-style-type: none"> • I do not know why he did not see the card at the first time • He easily found the task card but I do not know why • Difficult to find the right movement of the arm • It was too fast • It took me a long time to figure it out • I was afraid to do something wrong • Not clear why it says “start” <p>more difficult than the other task (2)</p>	<p>should also learn to see where the box is standing</p>
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Table 14: Results from thinking aloud during task 2.

Perceived Usability of the Robot

The SUS revealed a cumulative score of 65.83 for HOAP-3. This means that users accept the system. However, the experimental context, in this case the demonstration of specific motions and interaction via speech commands has to be taken into account.

User Experience

AttrakDiff: The comparison of the mean values for each scale shows that people positively experienced the robot (all mean values are around 1). This means that the usability of the robots is slightly positive, but there is still room for improvement of the user experience of the robot in terms of PQ, HQI HQS and ATT see below, Figure 7.

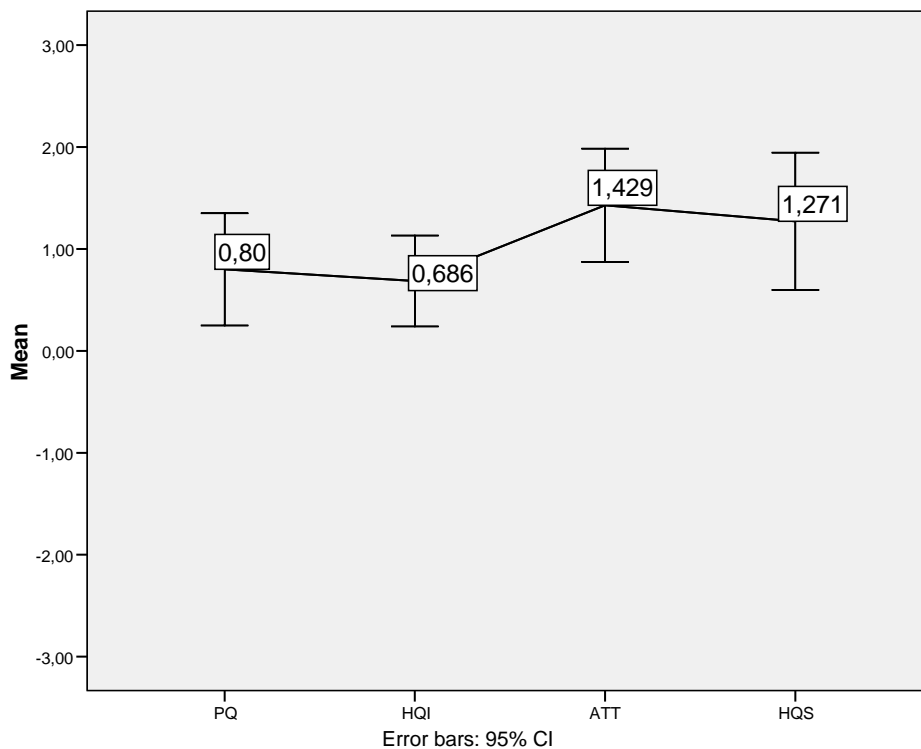


Figure 7 AttrakDiff diagram

UX-Questionnaire: All factors have average ratings higher than 4 what is quite positive, but like also visualized in the Attrakdiff diagram before there is still room for improvement. The high average indicator score of factor embodiment (mean: 5.6, S.E. 0.85) indicates that participants very positively experienced the design and the human like features (e.g. face, ears, eyes) of the HOAP-3 robot. Also quite good values were revealed for human-oriented perception (mean: 4.77, S.E. 1.49), feeling of security (mean: 5.16, S.E. 0.77) and emotion (mean: 5.45, S.E.0.74). The worst rated indicator is co-experience, with an average value of 4.05 (S.E 1.4), see Figure 8.

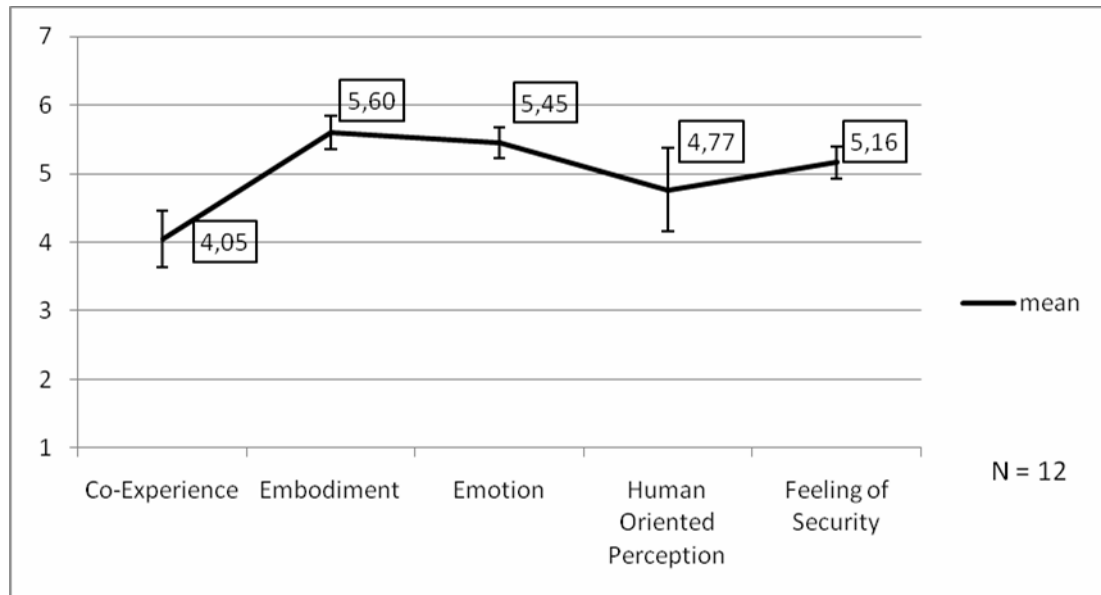


Figure 8 UX-questionnaire indicator diagram

NARS

S2 „Negative Attitude toward Social Influence of Robots“ is rated significantly higher before the test with HOAP-3, which means the participants’ negative attitude toward social influence of robots decreased through the interaction with the “HOAP-3” robot. S1 „Negative Attitude toward Situations of the Interaction with robots“ and S3 „Negative Attitude toward Emotions in Interaction with robots“ did not significantly change.

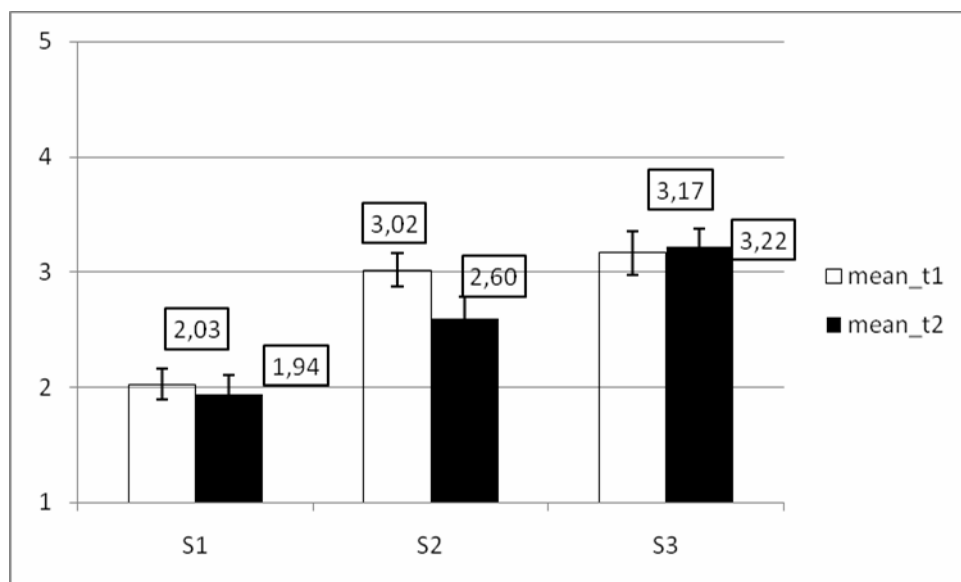


Figure 9 NARS diagram

SoAC- questionnaire

The indicator attitude towards technology is rated most positively with an average rating of 4.08 (S.E. 0.18). The indicators performance expectancy, effort expectancy, facilitating conditions and self efficacy reached rather good values around 3.5. The indicators attachment, forms of grouping, and feeling of reciprocity only reach mean scores around 3 as visualized in the graph, see Figure 10.

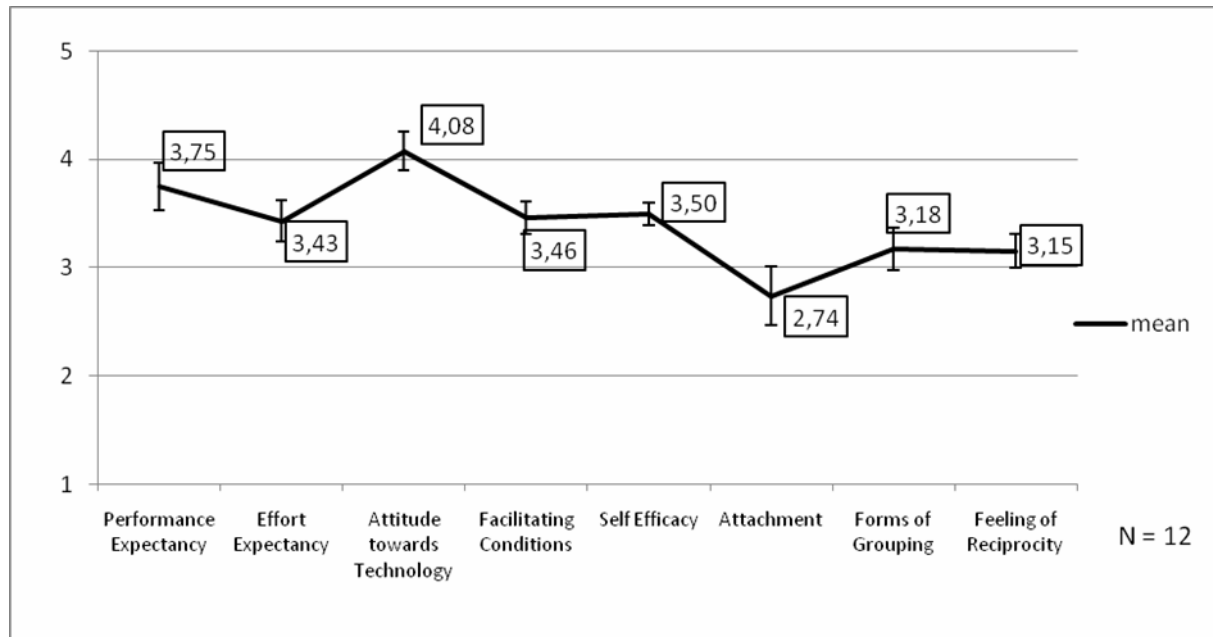


Figure 10 SoAc-questionnaire indicator diagram

PANAS: Scores for Positive Affect (PA) range from 10 to 50 (10 means no positive affect). Directly after interacting with HOAP-3 three female participants reach PA-values slightly under the normative average of 30.62 (sample with more than 1000 people), three female participants reach scores over the average normative female PA. Average female PA is 32.2857, in percent 58.4% of maximum reachable PA value, 8.4% higher than normative female PA sample. The average PA of the male participants is 27.25 (25.5% of max PA value), subadjacent normative sample score which is 32.06 (50% of max PA value). *In sum, the female participants were more positively affected by the interaction with HOAP-3 than the male participants.*

Scores for Negative Affect (NA) range from 10 to 42 (10 means no negative affect). The average NA score of female participants is much lower (14, or 33.7 % of max NA) than the average female normative score (16.68, 50% of max NA), an indicator that they were not distressed by the interaction with the robot. The average NA value of male participants (12.75, or 32% of max NA) is, alike the average NA of female participants, lower than normative score (15.2) as well. *Compared to the normative samples both female and male participants were minimally negatively affected by the interaction with the robot.*

Societal Impact Interview

When discussing about the question in which way robots could be integrated into the working life in future, the most popular imagination is that a robot could do repetitive boring tasks in manufactories, most popular attributed characteristic is they are working very precisely.

When participants think of ways robots could be integrated in future working life several things besides afore mentioned repetitive tasks in manufactories come into their minds. Very popular is the household-robot, who is cleaning, cooking or even in the role of a nurse helping elderly people alone at home with homework and even talking them and showing emotions against loneliness. A further job the participants' vision for robots is service-work (e.g. translation-robot, protocol-robot, computer-reparation-robot). A lot of participants are looking

forward to robots decreasing humans' dangerous work (e.g. bad air, mining). Some participants see robots driving cars and trains or flying planes. All in all, nearly everybody thinks robots are capable of doing physical tasks, like repetitive tasks in a manufactory, dangerous tasks like mining or service tasks like cleaning or cooking. Only some participants are of the opinion robots could do sophisticated tasks, like taking care of elderly people (even talking and showing emotions or educating children).

Concerning the question how life could change if robots are integrated into a construction area, all participants go along with the following point: Productivity will be improved if robots are introduced into a working area. Robots are able to work 24 hours a day, do not go on vacation, so the production will cost less and need less time. There are different opinions on the effects that an intensified employment of robots in working life could have. Some participants foresee positive effects if robots do jobs of human, e.g. there will occur more human resources for other creative jobs, some participants think of negative effects, they are of the opinion that the unemployment of human will increase, and as a result also the gap in society between higher educated and low skilled people will get bigger. They are apprehensive of an enhanced competition between low skilled people. What participants are looking forward to is that work will be saver if robots are introduced. There will be fewer accidents, and physical work is going to be easier with the help of robots. They like the imagination that robots can do a lot of dangerous work (e.g. mining), so they could reduce risk for human, and boring and dull work (e.g. repetitive tasks) in future. Concerning the dangers of working with robots one participant mentioned: "For example nuclear weapons are much more dangerous than robots, nevertheless robots should be supervised well." In general, participants do not think that robots are dangerous as long they are supervised.

Some participants mentioned they would not be happy if they had to work with robots every day, they think for example that working with robots would decrease interactivity between human and work would become less personal.

About the question how usage of robots in the working context will influence the future education system, the participants differ widely from each other. There is the opinion that is not necessary to learn new skills for the usage of robots at all, so there is no need to change education system. For example one participant mentions "It's like with new applications which can be used also by children even without reading an instruction book in the beginning", which implicates that robots are clear of danger for human. Some participants are of the opinion that it is enough if people who work with robots get a special training on programming and interacting with robots, but there is no need to take general educational measures. Other participants take the view that everybody should learn the usage of robots in school, especially dangers, ethical issues, responsibility and security should be educated. They think that the usage of robots cannot be learned in 5 minutes, it will take time to learn new skills. One participant sniffs a special chance in the usage of robots in education system. Children could playfully get inside robotic engineering. Generally participants say it depends on the degree of integration of robots. In case robots will be part of everyday life it would need more educational measures than if robots are only introduced into working area.

The last question was about how the society would support the use of robots in the future. Most participants think robots will be seen very positive in future, especially if they make life easier, are easy to control and do fewer errors. Partially they are of the opinion that robots

should only be supported if they contribute wellbeing and if humans benefit from robots, so it's important to prove the impacts on society before introducing robots.

One participant kept environment in mind and mentioned that it's crucial to work out a recycling plan for robots. Another participant emphasizes that film industry will play an important role, because it is able to create another sense of robots (e.g. the robots as companion). Generally participants assume that the support of robots depends on culture and age. They hypothesize "the higher developed a country is, the more it is willing to support the usage of robots". Some participants suggested introducing to gradually introduce robots into society, first support the research and design and then make it common. Participants with a market-oriented view say that there is no need for society to support; the usage of robots will grow on its own if well-working and relatively cheap robots come on the market. Especially domestic robots could leverage the usage of robots.

4.5. *User Study with HOAP-3: Remote Control Task*

Within the second user study with the HOAP-3 robot the following research questions were investigated:

- How do novice users experience the collaboration with the humanoid robot HOAP-3 when interacting via remote control?
- How do users perceive the system in terms of usability?
- Does the general attitude towards robotics change because of the interaction with the robot?
- How did the users experience interacting with HOAP-3?
- How did the interaction with HOAP-3 affect participants?
- How do people imagine a future society with humanoid robots as co-workers, after interacting with the robot?

4.5.1 Study Setting

The user study with HOAP-3 took place at the robotics lab of the Universidad Carlos III Madrid UC3M in Madrid from the 27th to 31st of October. 12 people (6 females, 6 males) with an average age of 23.75 years participated in the study; the youngest participant was aged 16, the oldest participant was aged 26. The nationalities of the participants were the following: Spanish (9), Columbian (1), Italian (1) and Guatemalan (1). All participants use the PC and internet every day, and most of them (9 out of 12) use their mobile phone daily or at least several times a week. All participants except one use a MP3 Player several times a week.

4.5.2 Instruments

At the user study at UC3M, participants were given two tasks in which they had to remotely control HOAP-3. Additionally, the following questionnaires had to be filled in: the AttrakDiff, the NARS, the SUS, the PANAS, the UX-questionnaire and the SoAc questionnaire. At last, interviews about societal impact were performed.

4.5.3 Procedure

Two tasks dealing with remote control of HOAP-3 via a computer interface had to be accomplished by the participants. Before starting with the tasks, participants got to know the HOAP-3 robot, the movements it is capable of as well as vision and navigation through the interface in a learning phase. Afterwards two tasks were performed by the means of a computer interface which enabled participants to see through HOAP-3's eyes and control its movements.

Before starting with each of the two tasks, a scenario was described by the instructor. The tasks as well as the scenarios are shown in Table 20.

Task 1	Task 2
<p>Scenario: <i>Your space shuttle has been hit by an asteroid and you were forced to an emergency landing. Your communication and internal ship monitoring system does not work - probably due to a damage caused by the crash. The good message is that you have the necessary material to replace the broken antenna for your communication system to send for help. As you are the only human survivor of the ship and the environment could possibly be dangerous for human beings, you decide to let this dangerous work be done by the ship's robot HOAP. At first you have to navigate HOAP to the exit of the shuttle.</i></p> <p>Instruction: <i>Help the robot to find its way through the corridor and find the door to the outside. The task is to move the robot by means of the computer interface. It is completed if you see the door through the interface and say "door found". The interaction with the robot is based on a computer interface, with which you can control the robot.</i></p>	<p>Scenario: <i>After you have accomplished the first task to get the robot HOAP out of the shuttle, you now have to help your HOAP to find the broken antenna. The problem is that your shuttle has several antennas of different shapes and colors and you cannot distinguish the defect one from the others by sight, but HOAP can. Inside the robot there is a mechanism which enables the robot to detect the malfunctioning parts.</i></p> <p>Instruction: <i>Your task is to control HOAP's movements again, while it is processing and checking the different antennas. In this task you have to help the robot to recognize the broken antenna. If HOAP has recognized a malfunctioning device it will put a square around it on the interface. The task is finished if you recognize the broken antenna through the interface and say "broken antenna recognized".</i></p>

Table 15: Scenarios and instructions given in Task 1 and Task 2.

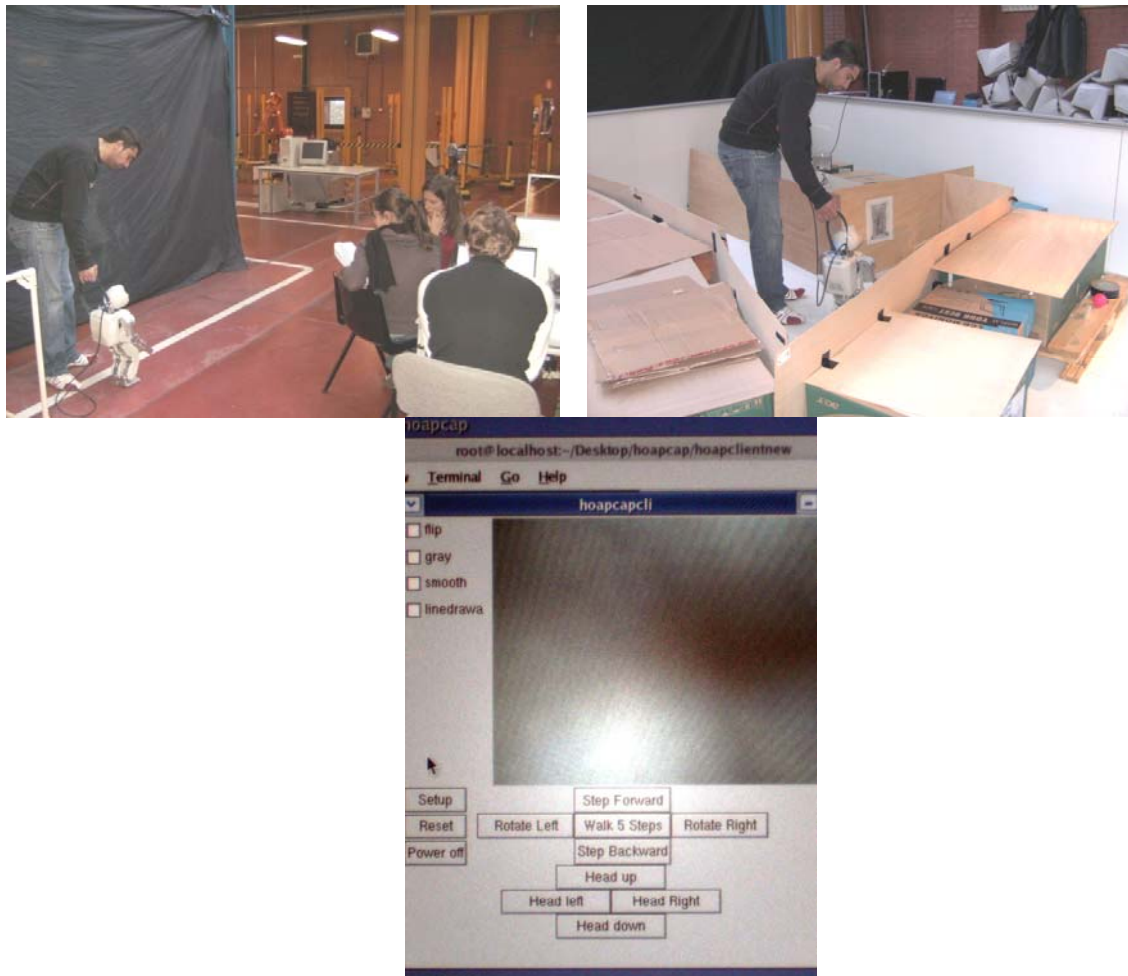


Figure 11 Remotely controlling HOAP-3

4.5.4 Overview of Results

Usability

	Task 1	Task 2
Average rating of difficulty	3	1.58
Average duration of task	7:13	0:55
Task completion	91.66% (11 out of 12)	100% (12 out of 12)

Table 16: Results from task 1 and 2.

Participants liked (answer count)::	Participants disliked (answer count):	Participants liked to improve (answer count):
<ul style="list-style-type: none"> • It was a little bit like I was the robot • I was surprised, it was very easy • I liked it as it was • Robot HOAP moves very exactly • Interface was very easy 	<ul style="list-style-type: none"> • Feedback about the position of the head is missing (“I did not know if the head is right or left because I didn’t remember all the head movement steps”) (5) • Robot is too slow(4) in case of emergency it 	<ul style="list-style-type: none"> • The Angle of vision should be wider (4) • There is only the possibility to make one step or five steps- it would be good if there was something in between (3) • There should be a sort of

<p>to use</p> <ul style="list-style-type: none"> • The movements of the head were very good • Interface is very friendly • Remote control was nice and intuitive • The interface is very simple (I only needed to press a button) • I felt secure because I was not the one doing the task 	<p>should be faster</p> <ul style="list-style-type: none"> • Don't get any information about the distance to the wall (3) • I did not know how much the robot moved (2) • Twice the robot would have fallen (shaking video transmission) • It was more difficult than I thought at first, the corridor was unreal • The movement was strange, a mix between fast and slow and you could not say "move a little bit faster or slower" • It was very difficult to use the buttons, I am not used to this • I did not know when the movement was finished • I was nervous because the robot was going to crash 	<p>feedback when the movement is finished (3)</p> <ul style="list-style-type: none"> • Interface doesn't indicate about position of the head (3) "I did not know if I was along with the body" • Make a clear difference between the body movements and the head movement in the interface(2) • The robots should have distance sensors (2) warning if it is too close to an obstacle and going to fall • Disable the buttons until the movement is finished (2) • It was more intuitive if the buttons were swap (head movement up-body movements down) • Interface should include a map (it's not enough to see through the robots eyes) • It would be great if you had a touch pad instead of a mouse • I would like to move head and body at the same time
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Table 17: Results from thinking aloud during task 1.

Participants liked (answer count)::	Participants disliked (answer count):	Participants liked to improve (answer count):
<ul style="list-style-type: none"> • The task was easy (all 12 participants) because I only had to move the head • Everything was fine, everybody can use this interface • It was easy to recognize the antenna 	<ul style="list-style-type: none"> • If you try to make a realistic situation problems don't get solved that easy • The task is too simple • If you said to me the broken antenna was a ball it would have been more easy 	<ul style="list-style-type: none"> • Similar to task 1 it was important to get feedback about the position of the head (4) • Probably it would be easier if robot had 360° vision • Button to get back to the original (center) position

<ul style="list-style-type: none"> • It is amazing how it can recognize objects • Easier than the first task • The robots is really pretty, I like it, I would like to work with it • Like in the first task I felt like I was the robot • This task I felt more secure because the robot was not moving (body) and the head was moving very smoothly 	<ul style="list-style-type: none"> • Is this the antenna? 	<p>of the head</p> <ul style="list-style-type: none"> • Label some sort of status message into the interface • A map was useful for instance a coordinate system in the screen • Different kind of interface was useful like rotation in goggle map. • Concerning the turning of the head it was important to say “you have reached the limit” • Joystick would be better • Disable the buttons until the movement is finished • Improve the interface (similar to Playstation, part of the movements on the left, part on the right side)
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Table 18: Results from thinking aloud during task 2.

Perceived Usability of the Robot

In this user study the SUS questionnaire had to be filled in by the participants with respect to the computer interface used for controlling the robot. The SUS revealed a cumulative score of 83.125 for HOAP-3, indicating that users liked the interface.

User Experience

AttrakDiff: As visualized in the graph and shown in the table participants were positive about solving tasks together with Robot HOAP-3 via remote control. Attractiveness was perceived best with score 2.179, see Figure 11. The pragmatic quality was rated worst, but still positive. Participants perceived the collaboration with HOAP-3 via remote control as very professional, inventive, presentable, pleasant, practical and motivating, but more undemanding than challenging and more cautious than bold.

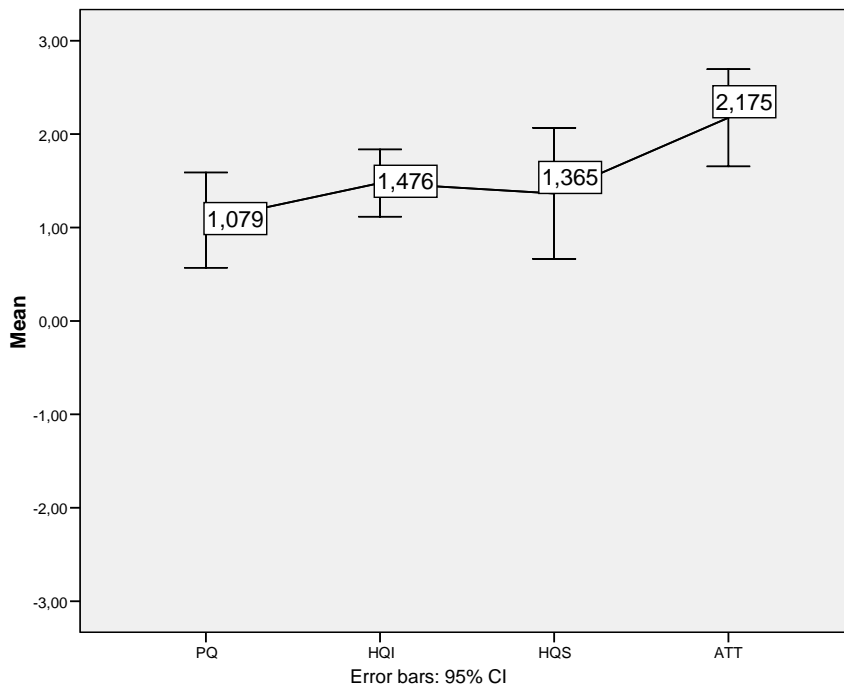


Figure 12 AttrakDiff diagram

UX-Questionnaire: Participants experienced the embodiment of the robot most positively (mean: 6.29, S.E. 0.25) followed by emotion (mean: 5.68, S.E. 0.23) and human-oriented perception (mean: 5.4, S.E. 0.41). Again the worst factor is co-experience which is lying in the middle field with a mean value of 4.08 (S.E. 0.43), as visualized in the graph, Figure 13.

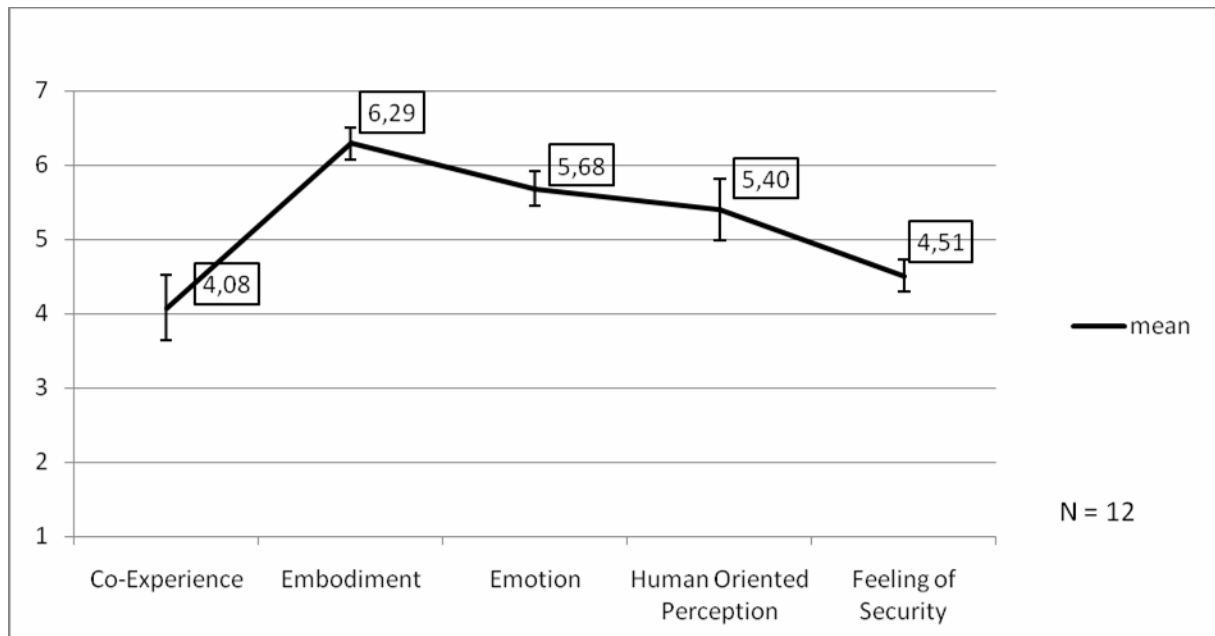


Figure 13 UX-questionnaire indicator diagram

Attitude towards Robotics

NARS: Negative Attitude towards Robots decreased through interacting with robot HOAP-3 regarding all three subscales. Negative attitude toward emotions in interaction with robots (S3) decreased significantly ($p=.046$).

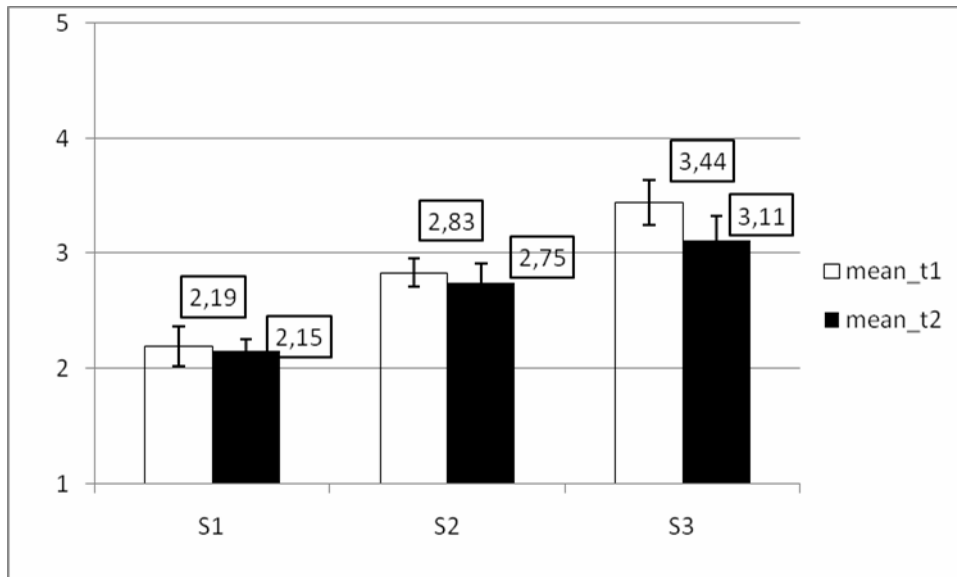


Figure 14 NARS diagram

SoAc- questionnaire

The indicator performance expectancy was rated the highest with a mean score 4.01 (S.E. 0.14) followed by effort expectancy (mean: 3.35, S.E. 0.11), facilitating conditions (mean: 3.35 S.E. 0.14), attachment (mean: 3.31, S.E. 0.09), forms of grouping (mean: 3.12, S.E. 0.13). By comparison the indicators self efficacy (mean: 2.12, S.E. 0.15) and sttitude towards technology (mean: 2.39, S.E.0.09) performed poorly, see Figure 15.

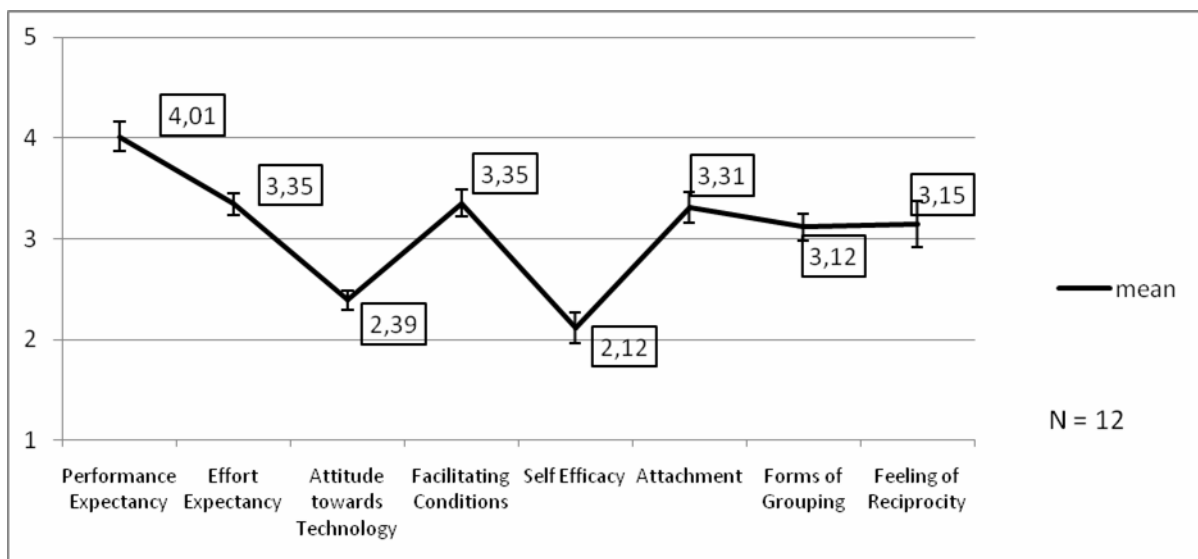


Figure 15 SoAc-questionnaire indicator diagram

PANAS

Scores for Positive Affect (PA) female range from 10 to 50 (10 means no positive affect). Normative female PA is 30.62 (which means that 50% of female normative sample have a better and 50% a lower PA score) Average PA of the female participants is 34.6. In percent: 69.6% of female are normally less positive affected than female participants after interacting with HOAP-3. Scores for male Positive Affect (PA) range from 10 to 48 (48 means maximum positive affect). Normative male PA is 32.06 (which means that 50% of male normative sample have a better and 50% worse PA score) Average PA of male participants is 37.67. 77.85% of normative male sample have a worse Positive Affect score than the male participants after fulfilling tasks together with HOAP-3. *The interaction with HOAP-3 affected the male participants slightly more positively than the female. However, both the female as well as the male participants were compared to the normative sample very positively affected.*

Scores for Negative Affect (NA) range from 10 to 42 (10 means no negative affect, 42 means maximum negative affect). Normative female NA is 16.68, 50% of the participants have a better and 50% a worse Negative Affect Score than 16.68. Average female NA is 14 with one female participant breaking away (NA= 27), without this breakaway the average NA is 10.6 in percent 16.99%. Thus, 83.01% of normative female NA sample have a higher (worse) NA score. Normative male NA is 15.2 (50% of normative sample lying over and 50% under 15.2) Average NA of male participants is 12.6. 68.59 % of normative male sample are more negatively affected than male participants after interacting with HOAP-3. *To sum up, the interaction with HOAP-3 resulted in very little negative affect for the participants. The female participants were less negatively affected than the male participants, but the male participants were less negatively affected than 68.59 % of the normative male sample as well.*

Societal Impact Interview

When discussing the question in which way robots could be integrated into the working life in future, the most popular imagination is that robots could work in construction site doing things faster and more precisely as well as making construction safer for human. Also very common is the idea of using robots in dangerous and risky situations like rescue, in space or in ocean. Some participants can imagine robots in health care taking care of the elderly or helping disabled people in managing everyday life. Using robots for all the trivial tasks at home (e.g. cleaning, cooking) also has a great vogue on condition that robots look humanlike and are affordable. One participant thinks of having robots instead of computers at home. Robots would also assist us greatly in medicine (e.g. brain surgery) and for other difficult things human can't do. One participant clearly states: "robots will never be intelligent, they will do automatically tasks no intelligence is needed for." while another participant says: "robots can do things that human can't and reverse. Human and robots can combine their strengths that would be great." – Quite contradictive opinions.

Concerning the question how life could change if robots are integrated into a construction area, $\frac{3}{4}$ of all participants say that introduction of robots will make work safer (probably this opinion is that popular because a lot of people die in construction sites in Spain as one participant tells). A second positive thing participants imagine is that work will be done faster and production will increase. The other side of the coin is that people will lose their jobs. One opinion is that human will supervise robots in future instead of doing the work themselves, another opinion is more people will work in office. "It is too risky to introduce robots into

construction, we all plan our life and our jobs, robots should not be integrated into our life” is mentioned as well. Two participants mentioned that education system has to change if robots are introduced into a working area, because there will be a need of people who know how to work with robots. Participants split over the question if robots make mistakes or not. On the one hand there is the opinion robots need to be supervised because they make mistakes, on the other hand robots will increase productivity because of their excellent precision and their characteristic not to make mistakes.

On the question how the usage of robots in the working context will influence the future education system, Participants are in agreement about young people learning more easily and due to this they think basics (e.g. How to interact with robots) should be learned as soon as possible. There is on the one hand the idea to make “robotics” to a subject in school like informatics (“it will be the same as with computers”). On the other hand participants suggest more specific and difficult knowledge could be taught at universities and trained at work. More than half of participants interpreted the question in a different way. They discussed if they can imagine robots as teacher. Five participants said: No, robots should not be teacher at all. Two participants are of the opinion that robots could be used in education but it should not be based on them (e.g. additional learning programs like we know from computers nowadays). One participant espouses more research because we don’t have enough knowledge if robots could be qualified teachers.

The last question was about how the society would support the use of robots in the future. This question was answered in many different ways. Most popular answer is that people support the usage of robots if they make their life easier (3 participants). Other suggestions were people can’t be afraid of something that is not intelligent and robots will not be intelligent as well as people have to see the robots then they will like them (“HOAP is so nice”). Two participants think people will be against robots because Hollywood Movies broadcast robots are dangerous because they develop a momentum on their own. Two participants are of the opinion that marketing and promotion through mass media will push on with the usage of robots. One participant mentions that not the robots but the humans are the problem. We need an international organization to avert that robots are creating war like weapons nowadays. Usage of robots should only be supported if robots do not hurt human. In future it will be normal, kids will grow up with robots is another opinion. An interesting finding is that a lot of people advice against robots taking care of children but at the same time they propose robots should take care of elderly and disabled people.

4.6. The two Field trials with ACE

This subsection describes briefly the settings of the two field trials with the ACE (Autonomous City Explorer) conducted in Munich, Germany together with TUM. Both field trials were mainly conducted to gain insights on social acceptance and societal impact of the robotic agent. Thus the both studies were conducted “in the wild” without informing participants beforehand. The studies were conducted taking in consideration the methodological concept of a sociological breaching experiment (for more details see Weiss et al., 2008): By introducing the robot into a public place the everyday routines of passers-by were disturbed and their reactions on and interactions with the robot were observed. Furthermore by-passers were selected by chance and voluntarily interviewed by means of a pre-structured social acceptance questionnaire.

4.6.1 Study Setting

The *first field trial* was conducted on a crowded public place, the Karlsplatz on July 30th, 2007. The place where the field trial took place was located at the end of a shopping street, frequented by many people. The robot ACE was used to simulate an autonomously moving robot in the pedestrian area. Although ACE is capable of autonomous navigation, the robot was remote controlled for security reasons. However, the illusion of an autonomous system was preserved as the operator as well as the researchers were well hidden for pedestrians passing by. 48 participants were selected by chance (on a voluntarily basis) to be interviewed based on a street-survey questionnaire (see Annex); 18 of them interacted with ACE over a touch screen before answering the questions. The age of the participants ranged from 18 to 75 years, the average age was 36.25. 33 participants were male and 15 female. One third of the participants indicated to have a university degree. More details on the first study can be found in Weiss et al. (2008).

The *second field trial* with the robot ACE was conducted in the form of a breaching experiment. This breaching experiment took place in a public space on a sunny warm September day, more exactly in a pedestrian zone in the centre of Munich on the 2nd of September 2008 from 10 am to 3 pm; altogether, 52 people were interviewed. Thereof, 39 participants were male and 13 were female, with an average age of 48.16 years (from 20 to 75 years). The main goal of the breaching experiment was to investigate the societal impact and social acceptance of the humanoid robot ACE by simulating the integration in our society. In the second study the robot operated autonomously, but could be controlled by an operator due to security issues. The operator only interfered if it was necessary. The appearance of the robot had been enhanced compared to the first experiment.

For both studies the following research questions were asked:

- Does the introduction of a robot into a public place violate human norms of social behavior?
- Does the ACE robot offer the necessary navigation, interaction and communication features to simulate a feeling of social acceptance among the pedestrians?

The first research question was answered by means of the observation data. In order to answer the second research question the data of the questionnaire were analyzed in accordance to the proposed factors.

4.6.2 Instruments

First Field-Trial with ACE

The behavior investigation by means of a user study in the field to assess the societal impact was based on a passive unstructured participant observation, combined with a street-survey based on interviews using a pre-structured questionnaire on social acceptance (see Annex). The questionnaire consisted of several items addressing social acceptance which had to be rated by the participants on a scale from 1 = “absolutely disagree” to 5 = “absolutely agree”. The social acceptance indicators are calculated by summing up the ratings of the participants and dividing them by the item count. The higher the value is, the more positively participants assessed the social acceptance.

Follow-up Field-Trial with ACE

At the follow-up study with the ACE robot, people were interviewed and have been asked standardized questions on social acceptance based on an adapted SoAc-questionnaire (see Annex) Again participants rated items on a scale from 1 = “absolutely disagree” to 5 = “absolutely agree”. The social acceptance indicators are calculated by summing up the ratings of the participants and dividing them by the item count. The higher the value is, the more positively participants assessed the social acceptance.

Furthermore the recorded video data was analyzed by means of an interaction analysis (Lueger and Froschauer, 2003). An interaction protocol was made including duration of the interactions and the conversations and gestures (what people said to ACE or to each other about ACE as well as their behavior when interacting with ACE). The conversations were analyzed by the help of “fine structure analysis” a method where the text is split up into small sequences that are chronological analyzed in terms of latent meaning, intention, everyday meaning, distribution of roles and options for the following sequence.

Therefore the text- sequences are deconstructed into small units of meaning, one unit of meaning should be at maximum one sentence long at the beginning it should only consist of a few words. Subsequently for every unit of meaning the following questions are asked (Lueger and Froschauer, 2003):

1. What is the superficial information of the unit of meaning, what does it mean in everyday life?
2. Which functions and intention could the producers of the text have had? What is the person going to achieve with the statement?
3. Which latent aspects can be found in the unit of meaning?
4. Which distribution of roles is given through the statement?
5. Which options appear for the next unit of meaning?

4.6.3 Procedure

First Field-Trial with ACE

The human operator used three different navigation strategies repeatedly during the case study:

- The ACE robot approached passers-by in the distance of the intimate space. The robot introduced itself with a female voice and then asked the by-passer if he/ she wanted further information about: (1) the ACE robot, (2) the Karlsplatz, (3) the Karlstor (important monument), (4) news, (5) Technical University Munich, and (6) the weather. The passers-by could select one of those options on the robot’s touch screen.
- The ACE robot navigated on the Karlsplatz without a direct goal in the distance of the personal and social space.
- The ACE robot stood still in the middle of the Karlsplatz and started approaching by-passers who showed interest towards it.

The first case study of the methodological set-up lasted two hours. The case study was based on a passive unstructured participant observation and pre-structured interviews with participants selected by chance.

Follow-up Field-Trial with ACE

In the second field trial, the task of ACE was to move from Odeonsplatz via Theatinerstraße to Marienplatz and back. These places are highly frequented by pedestrians and also by some cyclists. Because of several shopping possibilities, historical sights, cafes and restaurants, people of all ages and all educational levels saunter there. ACE asked passers-by for the way to either Marienplatz or Odeonsplatz. The passer-by could tell ACE where to go by first pointing in the right direction and then providing further information over the touch screen of ACE (e.g. how distant the goal was). The developers of the robot from TUM remained close to ACE for safety reasons but stayed unnoticed by the pedestrians because of the well frequented environment. Four researchers (unseen for pedestrians) from PLUS accompanied ACE. Three of them interviewed pedestrians who noticed ACE or interacted with it. One of the researchers observed the pedestrian’s reactions to ACE. A camera directly installed on ACE recorded the people interacting with ACE.

4.6.4 Overview of Results of the first study with ACE

Observation

During the field user study observational notes were taken. They were interpreted by means of an interaction analysis, resulting in 15 quantified behavioural patterns and a total of 192 observation counts (see Table 2).

Observed Behavioral Pattern	Count
Looking back to observe ACE	8
Searching for the face of ACE	10
Crowding around ACE	20
Short time interaction (no longer than two minutes)	18
Interactions longer than two minutes	32
Circling around ACE	4
Ignoring ACE when it is talking to a passer-by	5
Going on distance for observing ACE (from intimate space to social space)	18
Taking a picture	7
Controlling ACE with gestures or commands (waving, “follow me”)	19
Approaching ACE while passing by	18
Sending children first for interacting over the touch screen	4
Examining the hardware components of ACE	6
Talking about ACE in a group, aside from its position	6
Human-like interaction	17
Total observations	192

Table 19: Quantified behavioral patterns

Pre-Structured Interview on Social Acceptance

The high ratings for performance expectancy and effort expectancy indicate that the participants expect the robot to increase their performance in case they had to conduct tasks together with ACE without a high degree of ease. The participants showed a high belief in

their capabilities to use the robot which corresponds to their rather positive attitude towards novel technology. The results for forms of grouping and attachment showed mean values around three, indicating that the participants were indifferent if they experienced a bond or a common identity with the robot. The results for reciprocity were even below three, probably due to the limited interaction possibilities the robot offered. Only 54% (26 participants) perceived the robot as interactive, thus the limited interaction possibilities in a not controllable environment might highly influence the perception of reciprocity.

During the interview the questions on the factor cultural context were often discussed more intensively with the participants. The question whether robots are pleasant working colleagues was answered quite heterogeneously. 40% of the participants chose the middle answer category, arguing that they cannot answer the question, because they have not worked with robots so far. Eight participants answered “strongly agree”, arguing that robots could solve boring tasks or perform dangerous work for them. Similarly eight participants answered “strongly disagree”, arguing that they are afraid not to be able to handle the robot. The follow-up question, if the use of robots causes anxiety for the working place, was answered with “totally disagree” by 30 of the participants (62.5%). Additionally, many participants commented this question explaining that their working tasks were too complex for a robot to solve. Only three participants answered that they were very afraid to be substituted by a robot. 31 of the participants (67%) answered that they would strongly appreciate to own a robot.

71% of the participants stated that they would prefer to work with a humanoid and 25% would prefer a functionally designed robot. The reasons for the choice were diverse. The twelve participants choosing the functionally designed robot said for example. “A working robot should be a tool.”, “It should not look too human-like.”, “A human-like robot scares me.”, “This technical looking robot can fulfil working tasks more efficiently.” On the other hand, participants who chose the humanoid robot as working colleague stated e.g. “It looks more like a human, more friendly and likeable.”, “It can solve more tasks because it has arms, legs, and a head.” On the other hand the results of the follow-up question on how close participants would allow to be approached by the robot show that participants who had chosen the functionally designed robot stated a smaller distance. Six participants chose the intimate space and six the personal space. However, participants who preferred the humanoid robot, answered intimate space 13 times, 16 times personal space and five times social space. Gender, age, and education had no influence on the choice of the robot type.

4.6.5 Overview of Results of the Follow-up Field-Trial with ACE

Observation: Results Interaction Analysis

The introduction of ACE into public space triggered a lot of conversation on the robot as well as different emotional reactions: curiosity, joy, enthusiasm, amazement, but also (not very often) fear and anger. Facing a robot in public space was an unknown situation for the passers-by, so they tried to find out what other people thought about it and in which way other people explained and dealt with the situation by taking different measures (e.g. exchanging their ideas with strangers or directly going up to the robot and finding out by trial and error what the robot was made for and how to handle it). Some people were of the opinion that it was impossible that a robot was autonomously moving in public space (“There is someone sitting inside, isn’t it?” or “who is guiding it? It is that woman in the background”).

Do people demonstrate willingness to employ ACE for the tasks it is designed to support? Partly people demonstrated willingness: A lot of passers-by were happy to help ACE and went to interact with it on a voluntary basis even if they did not know anything about it and faced it without being asked to. They interacted with it in a public space in a high frequented shopping street, where a lot of people watched the scenario, which is also a strong indicator for acceptance. Other people showed un-willingness for instance by expressing contempt (e.g. "The autonomous robot is going to crash the window pane.")

Ease of use: Duration analysis shows (see table below) that the time until people give up interacting with the robot is limited. The first impression and experience counts, if the robot is not understood in the first minute, the people lose interest ("let's leave it alone...") The mean average duration of the interaction with ACE was 63 seconds; the successful completed interaction took 88 seconds (average duration), while cancelled interaction took 49 seconds (average duration).

Performance expectancy: People try to understand what the robot is doing by adopting its perspective. Thereby they expect the robot accepting a subordinate role and taking care of the humans and the environment ("he is broadly going around us", "he is reacting to obstacles"). However, the image of robots seems to be characterized by Hollywood-films ("I wonder if this is like Wall-e"). Some people interpreted the robot as a tourist attraction.

Attitude towards technology: People are very curious towards new technologies and many people are surprised in a positive way "it is able to go around me. I would not have thought that"; but some people are scared as well. However, most of the time curiosity prevails over anxiety.

Self efficacy: People like to prove to themselves, that they can manage the interaction with the robot. Especially children are very self-confident and actively approach the robot.

Forms of grouping: Some people show companion like behavior (e.g. "Let's have a look... Oh yes ... come on... take off"), the robot is directly addressed. But not everybody addresses the robot in 2nd person, even if they are standing right in front of it, a behavior which would be considered as extremely impolite when interacting with a human and an indicator that the robot is not accepted as a partner by everybody.

Feeling of Reciprocity: It is important that people recognize the robots reactions, otherwise they lose interest.

Security: People are looking out for the people who take care of the robot. They are of the opinion that it cannot be alone on its way, as that would be too dangerous; the quotation "It is going widely around us..." shows that people expect that their security is guaranteed.

Embodiment The most fascinating hardware feature of ACE was its mouth; probably because people conclude from the embodiment on the capabilities and functions and it is really hard to explain for them why it needs a mouth.

Pre-structured Interview: Social Acceptance

People perceived ACE very differently in terms of the social acceptance indicators. The best average ratings were revealed for the indicators attitude towards technology (mean: 3.96, S.E. 0.13) and performance expectancy with (mean: 3.97, S.E. 0.14). The worst average rating concerning the social acceptance of ACE has factor attachment (mean: 2.85, S.E. 0.14) indicating that participants can hardly imagine to develop an emotional bond towards the robot, see Figure 16.

The ratings of those people who interacted with ACE and those who only noticed ACE differ from each other. According to a comparison of means people who interacted with ACE rated forms of grouping ($p = 0.000$), self efficacy ($p = 0.004$), effort expectancy (0.004) of ACE and reciprocity ($p = 0.022$) and attitude ($p = 0.015$) significantly better than people who only noticed ACE but had not interacted with it.

Moreover, the factor reciprocity ($p = .025$) shows a significant difference between men and woman, indicating that men tend to rate the reciprocity of ACE higher than women. The other factors are not rated significantly different by men and women.

Another interesting result is that people between the age of 20 and 50 rated reciprocity ($p = 0.002$) and attachment ($p = 0.022$) significantly worse than people at the age of 51 or more. The factors forms of grouping, attitude towards technology, and self efficacy, performance expectancy and effort expectancy are not scored significantly different by the two age groups.

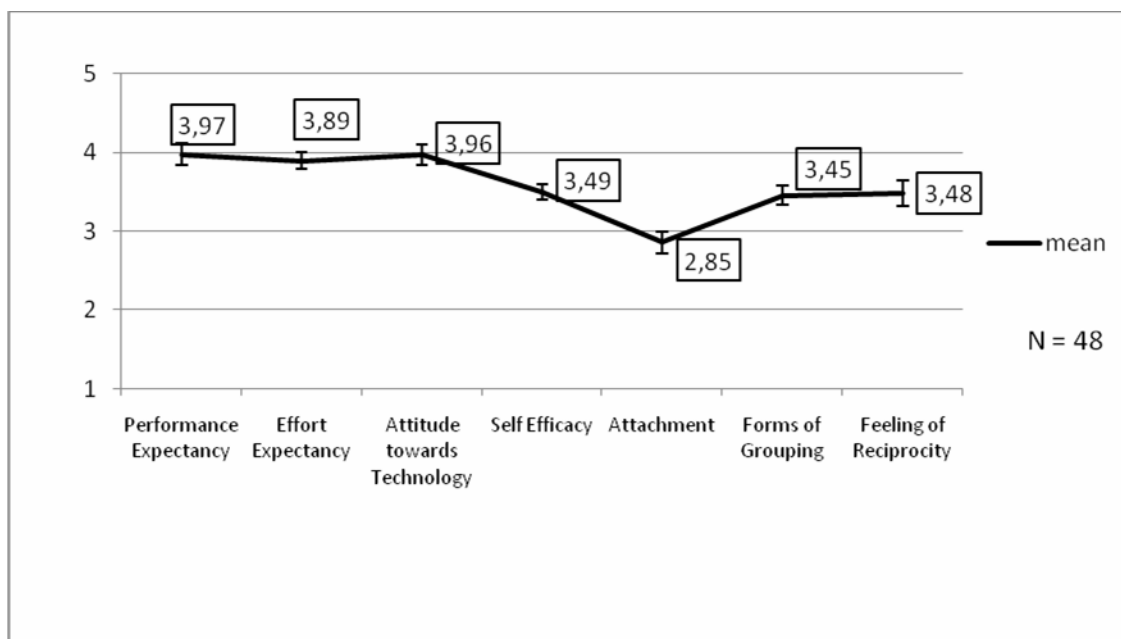


Figure 16 SoAc-questionnaire indicator diagram

4.7. Iterative Design of the Remote Control by the Means of Heuristic Evaluation

The task aims at collaboratively (HP-EIC, PLUS, UC3M) develop a tele-operator interface to control a humanoid robot. This interface should work on a touch screen interface. There are

two modes available: direct manipulation of the robot and goal oriented navigation of the robot map. The teleoperator interface has the following functions:

- Move the robot forward
- Move the robot backward
- Step the robot to the right/left
- Turn the robot to the right/left
- Stopping the robot
- Increase/decrease the speed of the robot
- Integrated robot camera view

4.7.1 Study Setting

In order to identify usability problems of the interface, a heuristic evaluation was conducted. The evaluation took place at the ICT&S Center and involved five expert evaluators. The experts (3 male, 2 female) were aged between 20 and 30 and had knowledge and practical experience in using a PC. They had expertise in Human-Computer Interaction as well as knowledge in designing a graphical user interface (two of them with advanced knowledge in that area). Moreover, they were familiar with the heuristics of Nielsen (1996).

4.7.2 Instruments

The heuristic evaluation consisted of two scenarios and a qualitative interview. Each scenario consisted of a stepwise presentation of required user actions and system responses and is defined by a context and a goal. Table 20 shows a detailed description of the two scenarios.

	Scenario I	Scenario II
Task	1) Move the robot by using the teleoperator interface 2) Increase the speed 3) Stop the robot	1) Take a look at the navigation and find out what you can do with it
Goal	Use the right buttons in order to move the robot to a desired location.	Find out which activities the navigation supports.
Context	You use the teleoperator interface for the first time. Move the robot forward, find out how to increase the speed of it and how to stop the robot.	You use the teleoperator interface for the first time and want to find out which possibilities the navigation offers to you.

Table 20: Description of scenarios used for heuristic evaluation.

4.7.3 Procedure

At first, the expert evaluators got a short introduction of the given interface and an explanation of the two scenarios. Then, they were asked to walk through the scenarios with a tablet pc, writing down the problems discovered on an excel sheet and assigning the heuristics of Nielsen (1996) to the problem. Finally, an interview with the expert evaluator was conducted. Based on the heuristic evaluation, a list of all the detected problems was created and sent to the evaluators to give a rating from 0 (no error) to 4 (very grave error) for the

different usability problems identified. Moreover, suggestions of how the detected problems could be solved were made by the researchers.

4.7.4 Results

The problems identified and rated within the heuristic evaluation are grouped in different problem areas and described below.

Labeling: one of the main problems identified during evaluation was the labeling of items. The meaning of the labels on the buttons was often not intuitive and unclear, and the purpose of some functions provided by the interface was also ambiguous. Sometimes, labeling of buttons was missing at all.

Design: The experts identified a list of problems concerning the design of the teleoperator interface. For example, the speed button posed problems and should be replaced with a slider which allows keen movement of the robot, and some buttons were too small. Moreover, it was not clear which mode was selected at the start of the system.

Problems concerning the content: The main problem here was the information overhead in the “Message Log Display”. As a solution, icons should be used instead of the message log display, and the amount of information should be reduced.

Navigational problems: A major drawback of the navigation function was due to an insufficient field of view of the robot’s camera. As the screen of the camera was too small, the controller was not able to see what was going on in front of the robot.

Structural problems: A structural problem was for example the alignment of buttons without grouping according to the different modes. Moreover, there are often insufficient or no feedback modalities, which makes it difficult for the user to know about the current state of the robot.

The things which were liked most are the colors of the interface and that everything which belongs to the navigation has the same color. Moreover, the goal pointing function makes the interface interesting. The things which were rated worst are the fact that the speed and the direction of the robot does not change simultaneously, what makes it difficult to make keen movements. Besides, it is not clear which mode is selected at system start. Figure 17: From left to right and top to down: First Interface Design proposed by HP, Interface recommended after the heuristic evaluation, second interface recommended after the second iteration, final interface developed by HP shows the design recommendations after each iteration step of the interface for remotely controlling a robot.

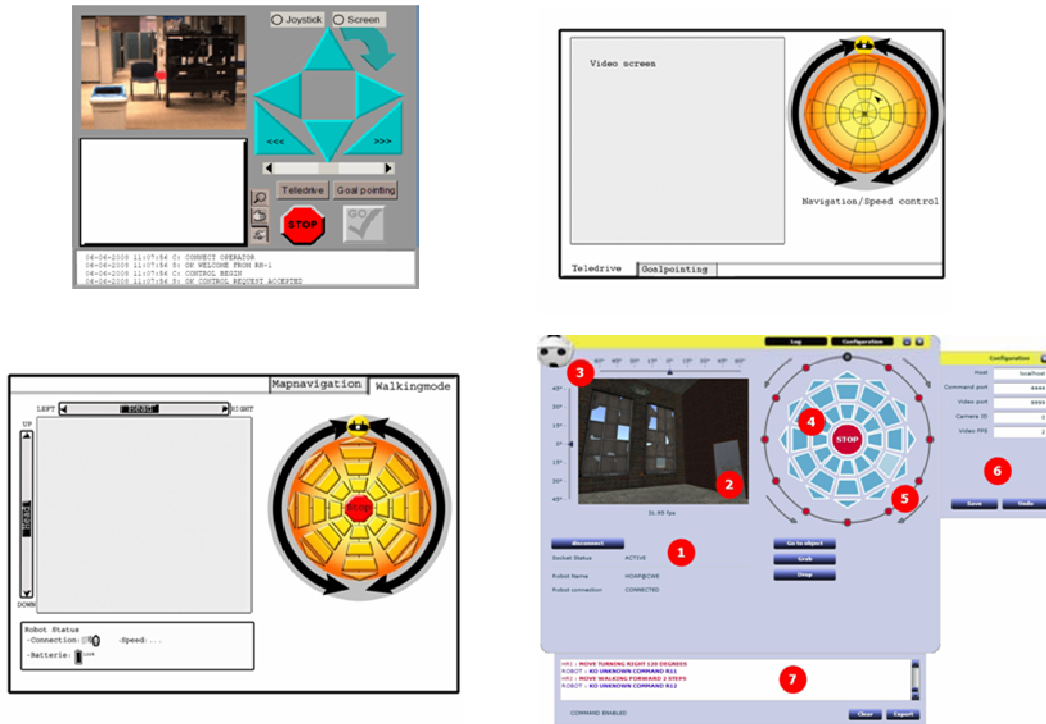


Figure 17: From left to right and top to down: First Interface Design proposed by HP, Interface recommended after the heuristic evaluation, second interface recommended after the second iteration, final interface developed by HP.

5. Comparative benchmarks-based evaluation in different applications and in different sectors

5.1. Introduction

One of the main objectives of the ROBOT@CWE project is to research and develop architectures with substantial support of the final users, looking at their requirements and experience.

The developing technologies within the project have to be evaluated in close collaboration with industrial partners giving a continuous feedback. So, different scenarios and prototypes are being developed in order to check the acceptance of IST-robotics systems by workers and companies' organizational models.

The project partners in the prototype evaluation have used the following humanoid platforms:

- HRP-2, available for AIST/CNRS partner
- Fujitsu HOAP-3, available for UC3M and EPFL partners

In D1.4@M06 different scenarios have been analyzed: among them, a crisis management in construction industry, several factory applications and planetary explorations in space industry. A demonstration of the capabilities of robot technology in a human-robot interaction

working environment and the acceptability of robots in a construction site scenario were conducted with the use of the humanoid robotic platform HRP-2. The scenario portrays one operator working at a construction area and in need of a special tool: a humanoid robot is supporting the worker in the task by providing the needed tools.

In order to evaluate usability and acceptability of the robotic platform in factory applications, a demonstration scenario with the robot HOAP3 has been prepared. The robot has been supposed to support workers in assembly tasks in a big fabrication plant, after having learned specified tasks by demonstration.

Regarding the space scenarios, the HOAP-3 robot has remotely commanded in one demonstration scenario symbolizing a communication restoration. Table 21 summarizes the different proposed scenarios.

Application	Brief scenario description	Platform used	Scenario location	Evaluation period
<i>Construction industry</i>	The robot is supporting the user by providing him with the needed tool.	HRP-2	CNRS (Toulouse)	8-11/07/08
<i>Factory</i>	The robot learns a specific task by demonstration (namely, move the robot's arm like it'll expect it to move it later on its own)	Hoap-3	EPFL (Lausanne)	10-15/08/08
<i>Space scenario</i>	The robot HOAP can be remotely controlled through an interface for performing the task of exiting the shuttle and look for the broken antenna.	Hoap-3	UC3M (Madrid)	28-30/10/08

Table 21: Summary of prototypes

In the following, we are going to summarize the results obtained by the user study restricted to the proposed scenarios.

5.2. Construction scenario

The construction industry is one of the most important and largest economic sectors in Europe the level of automation in construction is very low compared to other sectors, especially when considering the current technological advances. The introduction of a collaborative network of robots in the construction sites could lead to a substantial improvement of working conditions for humans and may potentially decrease the number of accidents and fatalities. Moreover, because the sector is getting less attractive, the use of robots could be necessary to compensate a future lack of workforce.

Three very different scenarios of humanoid robot use can be imagined. First, the humanoid robot can be used as a universal companion for helping the workers on the construction site. Humanoid robots can also be used as surveillance agent that can act quickly on the site when a dangerous situation occurs. This second scenario is compatible with the first one, as every

robot companion could act as a supervisor of its environment. Finally humanoid robots can replace humans for tedious and dangerous tasks, such as tasks in confined areas or in areas with risks of air pollution.

The preliminary HRP-2 user-study conducted by PLUS reveals that users accept the system, and a significant difference between the ratings of attitude towards robots is revealed; finally, users experience much lower negative attitudes after the experiment. Concerning the question how life could change if robots are integrated into a construction area, the participants forecast both positive and negative effects. A negative effect feared by the participants is unemployment as a result of the replacement of humans by robots; moreover, they are further concerned with regards to a competition between robots and humans. As assets, users perceive that there will be less accidents in future working life with robots, so work will be safer, also it is positively noted that work that only can be done by human will be more valued in a working future life with robots.

5.3. Factory scenario

The introduction of humanoid robots as an agent in industrial collaborative working environments might be of great interest for agile production lines such as cell-based factories or distribution networks. A direct application of the current development of humanoid robot to be used as a help could be the handling of packages and small-size items which could be co-handled with a human. The main issue is to find an efficiency threshold that, if reached, might make robots more efficient than classical human based low-cost production line. As it is very unlikely to have humanoid robots replacing completely humans in such environments, the key point is to have a very efficient collaboration between the three actors: information system – human – robots.

The main theme is to see a humanoid robot as multi-purpose advanced tool which can be redeployed easily depending on the tasks. Such kind of robot coupled with Virtual Prototyping of factory, and cell-based production line will decrease the cost of changing a product line and make a company more reactive to the customer needs. Humanoid robots have the advantage of versatility. Indeed on the same platform a large range of functionalities are possible: maintenance, pick-and-place, remote intervention, etc

The first user-study with HOAP-3 based on two learning tasks conducted by PLUS reveals that users accept the robotic system; also it is revealed that participants experience a high decrease in their negative attitude toward social influence of robots through accomplishing tasks together with the robot HOAP-3. On the question of impact of introducing robots to the manufacturing process participants feel that productivity could be improved if robots are introduced into a working area. Participants believe that robots will be able to work 24 hours a day so production will cost-less and need less time. Some participants foresee positive effects if robots do jobs in the place of humans and there will occur more human resources for other creative jobs. Some participants think of negative effects, they are of the opinion that the unemployment of human will increase, and as a result also the gap in society between higher educated and low skilled people will get bigger.

5.4. *Space scenario*

Humanoid robots are also going to join the field of space applications. In space robots can support or replace people to carry out tasks that are too dangerous, too difficult, repetitive, time consuming or even impossible for humans. They can also be faster and more precise than people. The most advantageous opportunity is the zero gravity in outer space, 1/6th of Earth gravity for the Moon and 1/3rd for Mars, respectively. This means that everything weighs much less than on Earth and even the heaviest object can be moved and raised with little effort, so a small robot can move huge objects: for instance, a planetary colony where humans and robots work and “life” in a coexisting way.

Robots can perform risky tasks at a lesser cost and risk as humans could do, hence they appear as very relevant options in a number of situations. However, humans are still much more prone to cope with contingencies, to take the initiative and to demonstrate common sense in complex situations.

The second HOAP-3 user-study based on two remote control tasks conducted by PLUS reveals that users like the system, also it is revealed that participants’ negative attitudes towards Robots reduced significantly through interacting with robot HOAP-3. On the impact of introducing robots in everyday future life participants feel that people support the usage of robots if they make their life easier. Usage of robots should only be supported if robots don’t hurt human. In future it will be normal: kids will grow up with robots. Very common is the idea of using robots in dangerous and risky situations like rescue, in space or in ocean. Using robots for all the trivial tasks also has a great vogue on condition that robots look humanlike and are affordable.

5.5. *Conclusions*

Generally, participants associated positive expectations as well as negative expectations and fear about the future when working with robots in collaborative working environments. One of the arguments concerning the collaboration with robots is that they will never be able to substitute colleagues at work, as humans are needed for good social contact. Most of the participants agree that a robot will never be an equal working colleague for them. Most participants agree that a robot should replace a human being only in case of monotonous or dangerous work. Robots should only adopt physical work and support humans.

On the integration of robots to the working area, it is expected that robots would help the increasing productivity. Robots are able to work 24 hours a day, do not go on vacation, so the time and cost production will be reduced. There will be both positive and negative effects. Among the positive results of having robots working in lieu of humans, users perceive that the “saved” human resources may be employed for artistic jobs. Work will be safer if robots are introduced in the working area, there will be fewer accidents, and physical work is going to be easier with the help of robots. They like the imagination that robots can do a lot of dangerous work, so they could reduce risk for human, and boring and dull work in future.

On the other hand, as expected, users also reckon with the possible increase in human unemployment and, as a result, they expect that the gap in society between higher educated and low skilled people will increase. In general, participants do not think that robots are

dangerous as long as they are supervised. The different results in user experience, social acceptance and societal impact are shown in the resuming tables from Table 22 to Table 24.

Application	Usability	User Experience
<i>Construction</i>	users accept the system	People experienced with the robot report rather neutral attitudes (all mean values are around 0). This means that there is still room for improvement of the user experience
<i>Factory</i>	users accept the system	People positively experienced the robot (all mean values are around 1). This means that the usability of the robots is slightly positive, but there is still room for improvement of the user experience of the robot
<i>Space</i>	users like the system	Participants perceived collaboration with HOAP-3 based on the computer interface as very professional, inventive, presentable, pleasant, practical and motivating, but a bit more undemanding than challenging and more cautious than bold.

Table 22: User experience

Application	Social Acceptance
<i>Construction</i>	After the experiment/test a significant difference between the ratings of attitude towards robots is revealed, the rating of the “negative attitude toward situations of the interactions with robots” is significantly lower than before the experiment.
<i>Factory</i>	Negative Attitudes where rated significantly higher before the test with HOAP, which means that participants experience a high decreased in their negative attitude toward social influence of robots through making tasks together with the robot “HOAP”
<i>Space</i>	Negative Attitude towards Robots got lower through interacting with robot HOAP regarding all three subscales. Negative attitude toward emotions in interaction with robots decreased significantly.

Table 23: Societal acceptance

Application	Societal impact	
	Positive effects	Negative effects
<i>Construction</i>	<ul style="list-style-type: none"> - less accidents in future working life with robots - work will be safer - work that only can be done by human will be more valued in a future with robots. 	<ul style="list-style-type: none"> - unemployment as a result of the replacement of human by robots - competition between robots and humans.

<i>Factory</i>	<ul style="list-style-type: none"> - productivity will improved - more human resources for other creative jobs. 	<ul style="list-style-type: none"> - unemployment will increase - the gap in society between higher educated and low skilled people will get bigger.
<i>Space</i>	<ul style="list-style-type: none"> - people support the usage of robots if they make their life easier. - using robots in dangerous and risky situations like rescue, in space or in ocean - using robots for all the trivial tasks also has a great vogue on condition that robots look humanlike and are affordable. 	<ul style="list-style-type: none"> - robots need to be supervised because they make mistakes

Table 24: Societal impact

6. Insights on Usability

Overall question: *How do users perceive the system in terms of usability?*

Which systems were investigated?

- HRP-2
- HOAP-3 (learning tasks & remote control tasks)

After several user studies of the different robotic platforms the usability problems found by means of expert- and user-based evaluations were rather similar. The main usability problems identified concerned lack of feedback, the visibility of system status and the flexibility of use, as shown in the heuristic evaluation of the different robotic platforms and the user studies with HRP-2 and HOAP-3.

In the preliminary HRP-2 user study major usability problem was the time the robot needed to perform the command. It will be important for future human-humanoid collaboration scenarios to reduce the reaction times of such platforms, for instance the time between the given commands, the response of the commands and the final the processing of the task. Similarly, the ACE-follow-up study showed that the time of a successful interaction is limited, as the interaction with the robot was canceled within 60 seconds if the robot did not react as expected.

The preliminary HRP-2 study and the first HOAP-3 study showed that participants like speech commands as input modalities. They experienced it as intuitive and easy to use. However, usability problems occur as soon as the robot does not react as expected to a command. Additionally, in order to get a better usability and increase the efficiency of the robotic system, not every step of the task should require a command (e.g. look down), which means less task orientated and more goal orientated. Above all the robotic systems are lacking in robustness, as they are little error preventing and provide little support for the users, e.g. when a command was not understood by the robot.

In the learning task participants rated the usability of the robot as acceptable. Some of the participants stated that learning by demonstration is a very natural interaction style, but only if the robot states its feedback about the learning process. The interaction based on direct contact with the robot increased people's anxiety to damage the robot, which reduced the efficiency and effectiveness in the interaction.

Regarding the usability of the computer interface for remotely controlling robot, participants preferred an interface with little functionality. Most of the participants liked to control the robot with the computer interface, which resulted in a good rating of the interface by means of the SUS questionnaire at the second HOAP-3 user study. In order to improve the usability of such an interface an iterative design approach showed to be very useful (see chapter 4.7 iterative design of the remote control by means of heuristic evaluation).

To sum up, participants liked the natural (speech control, learning task) way of commanding a robot but also complained the technical realization of them or the set-up of the experiment. Furthermore an iterative development of a tele-operator interface could be promising in terms of usability.

7. Insights on Social Acceptance

Overall question: *Does the general attitude towards robotics change because of the interaction with the robot?*

Which systems were investigated?

- HRP-2
- HOAP-3 (learning tasks & remote control tasks)
- ACE

For getting insights on how acceptance of humans collaborating with robots can be characterized, interactions with the HRP-2 robot, the HOAP-3 robot or the ACE robot, as well as discussions within a focus group were drawn on.

The results of the user studies show that the general attitude towards robots was influenced by the interaction with the robot. After interacting with HRP-2 or HOAP-3, most participants had a more positive attitude towards robots in general. The attitude measured concerned the following three areas: "Situation of the Interaction with Robots", "Social Influence of Robots" and "Emotions in Interaction with Robots". This implies that real-life interaction with a robot seems to compensate negative attitude and upgrade attitudes to more positive ones.

In general, the results show a rather high acceptance of humanoid robots. This acceptance is characterized by the expectation of improvement of job performance and work conditions due to the integration of robots in working life. They think that robots are easy to use and that collaborating with them needs no additional knowledge or extra effort. All in all, participants are quite motivated to integrate robots in their working life. These results indicate that people are open to introducing robots into working life.

The rather positive perception of robots, characterized by a positive attitude and rather high acceptance of robots, could be explained by positive experiences made during the interaction with HOAP-3 or HRP-2. In general, many participants were enthusiastic about the robot's abilities and appearance. Findings from the field trial with ACE confirm this: People who interacted with ACE showed higher acceptance than people who only noticed ACE but did not interact with it. Real life-interaction with robots therefore seems to bring down prejudices towards human-robot collaboration. Furthermore, it can be assumed that the observed effects will be stronger when human-robot interaction takes place over a longer time span. To investigate this assumption, long-term studies are required.

Uncertainty was declared by participants for two factors of social acceptance: emotional attachment and reciprocity. In the user studies with HOAP-3 and HRP-2, participants were undecided if robots could create a feeling of attachment in them. In the focus group study, participants even expressed fear about the fact that people could develop emotional attachment towards a robot. The more positive result of the user studies could again be explained by the real-life interaction, which seems to reduce negative attitude and fear towards robots. However, emotional attachment is a construct which develops over time, and therefore cannot be addressed properly in short-term studies. Only long-term studies can reveal insights into how much people can get emotionally attached to robots.

Participants were not sure if the relationship with robots would be reciprocal and therefore would comply with the principles of give and take. These results of the user studies are in line with the results from the focus group, where participants indicate that a robot is only another type of technical device and will never be an equal working colleague for them. All in all, people rather perceive robots as tool or instrument and not like a human colleague at work.

However, real-life collaboration with robots could probably change this opinion (the tasks which had to be accomplished together with the robot during the user studies were rather in the form of giving commands to the robot and not like solving a problem together).

Focus group results show that people are open to robots as working partners as long as there is a clear distinction between a human and a robotic working colleague, meaning that robots are designed functionally. Functionally designed robots were not directly addressed within the user studies; however, participants did not express the desire to have functionally designed robots instead of humanoid ones.

Another interesting insight found was the fact that acceptance is influenced by the operation mode (Weiss et al. 2009c). This could be shown by the participants' comments in the focus group, which showed that people feel more secure when the robot was remotely controlled (instead of acting autonomously).

8. Insights on User Experience

Overall question: How do novice users experience the collaboration with the robot?
Which systems were investigated?

- HRP-2

- HOAP-3 (learning tasks & remote control tasks)

For getting insights on how users experience interactions with the HRP-2 robot and the HOAP-3 the lab-based user studies, as well as discussions within a focus group were taken into account.

Both robotic systems in all user study scenarios showed room for improvement in terms of user experience. Above all the Attrakdiff questionnaire data provided evidence that the pragmatic quality is always rated best, but the more user experience related concepts like hedonic quality and attractiveness of the system were rated rather low.

When discussing user experience aspects of the robotic systems with the participants during the retrospective think aloud, attributes that were often assigned to the robots were novel, good, likeable, and innovative. That shows that the so called novelty effect heavily influences the experience of the robotic system. In the preliminary HRP-2 study one participant even stated: “Wow, I never expected robotic technology that easy to use, you just need to talk to it.

Regarding the UX-questionnaire up to now the scales of the questionnaire could not be validated, due to the small sample size. However, some factors already showed evaluation tendencies: Emotion was rated rather positive in all three lab-based user studies, indicating that the interaction with the robotic systems definitely causes emotions on the user side (based on that fact we decided to use the PANAS questionnaire to gain more insights on the “type of emotion”).

The indicators embodiment and human-oriented perception both showed the tendency that the HOAP-3 robot was experienced more positive due to its sizes and “cuteness” (the online survey should give insights by means of a bigger sample size if this assumption can be verified). The focus group additionally revealed for the indicator embodiment that in collaborative settings participants prefer a functional designed robot, due to the fact that it is easier for the participants to assess the tasks a robot is able to perform. This indicates that it will be relevant for future human-humanoid collaboration scenarios to communicate the robots’ functionalities to the users.

The indicator co-experienced is up to now rather low, however its rating heavily depends on the study scenario: in the preliminary HRP-2 user study participants did not experience the scenario as collaboration, but as master -slave setting, where the robot is just a sophisticated tool; in the first HOAP-3 study (learning task) people experienced collaboration (for this study the reliability test for the co-experience indicator even reached a Cronbach alpha of 0.8!). Similarly the second HOAP-3 study revealed better results for the co-experience indicator, as it was experienced like “seeing through the robot’s eyes”. One participant even stated “I felt like being the robot, myself”.

The factor feeling of security was difficult to measure in the lab-based user studies, as participants expected the system to be safe in such a setting (see chapter 10 on Lessons Learned and Recommendations). Surprisingly also the second field trial revealed a similar result, that people expect a robotic system used in public to be safe. However in the focus

group study participants stressed that feeling of control and safety is a key issue in human-robot collaboration.

The PANAS questionnaire provided interesting insights in the positive and negative affect of participants after interacting with the HOAP-3 robot. In the first study it could be shown that women had a higher than normal average positive affect after interacting with HOAP-3 and a lower than normal average negative affect (males were around average for negative and positive affect). This indicates that direct contact interaction with the HOAP-3 robot supports a positive user experience for women in terms of emotion. In the second study the remote controlled HOAP-3 robot increased the negative affect for both genders. This indicates that even though the remote control interface was perceived positive in terms of usability it offered a worse user experience in terms of emotion. The most often expressed affects when interacting with HOAP-3 in general were fear and surprise

9. Insights on Societal Impact

Overall question: How do people imagine the future society (after interacting with a robot)?

Participants were asked after interacting with the following systems:

- HRP-2
- HOAP-3 (learning tasks & remote control tasks)

The answers of non-experts were relatively similar between the three different European test settings and the different humanoid robots presented in the user studies. Thus it appears that the imagination of the future society with robots does not vary much across Europe.

On the one hand the people are quite skeptical of the usage of robots in future, mainly due to the fear of being replaced by robots in their jobs and get dismissed, as robots are supposed to work 24 hours a day as well as more precisely and faster than human. On the other hand people are looking forward to an easier life with household robots and more creative jobs for human, as robots will do the monotonous and repetitive tasks. Furthermore robots are perceived as positive and helpful, as they will release people from dangerous work (e.g. mining). According to Asimov's 1st law "A robot may not injure a human being or, through inaction, allow a human being to come to harm" people emphasize the human's safety: Robots should only be used if it is guaranteed that no human will get hurt. While the handling of robots is partly seen as easy and intuitive and no training or education is required, the other part of the people thinks of robotics as school subject as well as training lessons at work, where among technical ethical issues need to be taught.

Generally the employment of robots is presumed to be a benefit cost question. If robots are affordable, easy to use, and contribute wellbeing, people will buy and use them. This means that if the benefit of adopting robots is higher than the arising costs, robots will be adopted at the working place as well as in daily life. The ease of use is mentioned as a further basic employment factor. The role users assign to robots in working environments seems to be very clear – in future, robots will do manual tasks and no tasks which require (creative) thinking. However, people are of different opinions concerning robots doing more sophisticated tasks like taking care of the elderly and helping disabled people in managing everyday life.

Furthermore participants stated that they think it is useful to promote robots by mass media. Also film industry is playing a great role because of its ability to create a sense of robots as companions.

10. Recommendations and Lessons Learned

This chapter provides a summary of the different lessons learned and recommendations regarding the methodological approach of the eight evaluation studies.

10.1. Heuristic Evaluation of the Different Robotic Systems

- A heuristic evaluation of robotic systems can also be conducted by using video-taped human-robot interaction. Especially when robotic prototypes are not available or the evaluation should be done across different countries, heuristic evaluation of video-taped human-robot interaction is reasonable and rather effortless.
- Videos turned out to be a reasonable tool for simulating human-robot interaction instead of performing real human-robot interaction.
- A heuristic evaluation based on video prototypes represents a fast and cheap method for identifying usability problems of robotic prototypes.
- Manuals and templates provide a good support for the expert evaluators when no test leader is present.
- Group discussions can be valuable enriched with visual or creative stimuli (e.g. videos or building sets).
- Video-based heuristic evaluation can be beneficially applied when you want to identify usability problems of robotic prototypes which are not easy available.
- Video-based expert evaluations should be supported with manuals, examples and templates when no test leader is present.

10.2. Focus Group with HRP-2: Autonomous versus. tele-operated

- Focus groups represent a fast and cheap qualitative method for gaining first-hand experiences on people's attitudes toward certain aspects of Human-Robot Interaction. As attitudes are often influenced by group discussion processes in everyday life, e.g. when a humanoid robot would be introduced into a real working environment, employees would also discuss about the robot and their attitude towards it together.
- Using a video of a human-robot interaction turned out to be a reasonable approach to address the general attitude of people towards robots as working colleagues. The discussion is stimulated by the video scene, and first insights on people's attitude towards robots can be gained quickly.
- Videos are a reasonable tool for simulating human-robot interaction instead of performing real human-robot interaction.

- The type of the robot as well as the task which is conducted probably influences the results. However, this is also true for studies where real interaction with the robot/real accomplishment of tasks is done. This effect could be addressed by conducting comparative studies with different types of robots or tasks.
- Including “creative methods/stimuli” like the “robot-building-set” into a focus group turned out to be a good approach, as it boosted the participants’ creativity and heated up the discussion. Moreover, things which are often hard to communicate for people can be represented by the outcome of the creative work.
- Focus group discussions can be valuable enriched with visual or creative stimuli (e.g. videos or building sets).
- Focus groups should be applied at a first stage of a human-robot interaction investigation, i.e. to gain first insights on people’s attitudes quickly and cost-effectively.
- Videos can be used in order to simulate human-robot interaction at a first stage of your investigations.

10.3. Preliminary User Study with HRP-2: Whole Body Motion Task

- People experience human-robot interaction, which is only based on speech commands not as collaboration. In fact participants explained that it was more like working with a sophisticated tool that reacts on speech commands than with a working colleague.
- Feeling of security can hardly be observed in a lab-based setting, where an operator always have to take care of the motions of the robot, as participants expect their security as guaranteed in such a setting.
- The recruitment of novice users is not as easy as expected in the beginning; above all the educational background of the participants has to be taken into account. In the retrospective think aloud and the societal impact interviews it became obvious that people heavily relate to their education and profession: “As I study computer science, I have a mental model how the vision of the robot works.” “As I am working in education I can tell you that robots should not teach children!” etc.
- Regarding the procedure of this preliminary user study it is worth to mention that participants experienced it as positive that they had the opportunity to fill in the NARS questionnaire twice. “That’s good; I already changed my mind about robots”. Similarly also the study duration and workload was experienced as acceptable for the study participants. Thus we kept that setting for the other lab-based studies.

10.4. User Study with HOAP-3: Learning Task

- Learning by demonstration based on direct contact interaction and speech commands is a valuable approach to bring naïve users closer to robotic systems.

- The ease and intuitiveness of use are the basic acceptance factors, but also the “humanness” of the robot when acting as a working colleague is an important acceptance factor as well as the embodiment of the robot (the embodiment of the humanoid HOAP-3 robot was perceived very positively in the teaching by demonstration scenario (but clearly this result was biased by the study setting).
- An indicator for the value of learning by demonstration with naïve users was that the perceived difficulty of the tasks did not influence the participants’ general satisfaction with the system. This indicates that naïve users give the robot a second chance even though they perceived a previous teaching attempt as difficult or unsatisfying.
- Woman set a higher standard to the social interaction capabilities of robots.
- The results of the user study show a positive attitude towards technology in general and robotics in specific as well as a positive image of robotics. However, the first interaction with a robot influences the general attitude towards robotics; in the case of the presented user study a substantially positive effect on the general attitude toward robotics could be examined.
- Provide some basic technical background information also to naïve users, as a lack of background information leads to misunderstandings and frustration, as people like to reconstruct the robot’s way of perception. The participants do not like if things happen, they cannot explain to themselves. This can be avoided if the robots capabilities are introduced in educational lessons beforehand.
- Avoid fears of contact when learning by demonstration by allowing enough time for questions and the introduction of the robot in learning tasks.

10.5. User Study with HOAP-3: Remote Control Task

- The participants liked the computer interface of the remote control, because of its simple design.
- Regarding the set-up of the user study, participants complained that the scenarios were not realistic enough, because it was a space scenario and the environment did not look like it at all. Furthermore the second task was too easy, complained by some participants. The scenario, the environment and the objects in the scenario should match with the real world (the “antenna” which had to be found in the second task was represented by a ball, which confused some participants).
- Male and female participants were affected very positively, although the interaction with the robot resulted in a slight negative affect. Hereby female were less negatively affected than male regarding the interaction of the robot. However in general it shows that the interaction with the robot even through a computer interface highly affected the participants.
- The participants had problems controlling the robot through the maze because of the lack of the missing feedback provided by the interface. The participants liked the little functionalities of the interface, but nevertheless feedback options were missing. Some

participants even counted how many times he/she moved the head of the robot in order to be aware of the position of the head.

- In order to move the robot more effectively, the movements should be more scalable.
- The video screen shown in the interface, coming from the robot, should be wider which would lead into a better performance of the task.
- As the user interacts with the interface the actions of the user should be monitored with a screen monitoring tool too, in order to get better results from the video study.

10.6. The two Field Trials with ACE

- People expect their security as guaranteed. A robot moving in public space has to accept a subordinate role to the humans and the whole environment (e.g. the robot has to sidestep).
- A lot of people show willingness to interact with a robot they are extemporaneously confronted in public space, which is an indicator for high acceptance and interest. However, not everybody is pleased to be abruptly faced with a robot, and some people are even scared. To avoid that people get scared great care should be taken on the human-human interaction- and movement-rules in public space (e.g. give human a wide berth or give warn signals when drawing near, as people are used to rely on their aural sense as well).
- The first impression counts. The robot has to be easy and intuitive to use, naïve users must be able to a successful interaction immediately. If the human-robot interaction does not work (if the robot does not show reaction) within one minute, the passersby lose interest and break off the interaction. If the human-robot-interaction works immediately, people are pleased to be able to handle the robot and willing to finish the interaction. Thus the usability of the robot should be iteratively investigated with naïve users in laboratory before being used in public space.
- People reason the capabilities from the embodiment (if it has eyes, people assume that it can see or if the body of the robot is huge and box-like, some people assume a human is sitting inside and navigating and controlling the robot).
- Curiosity prevails over anxiety. People are curiosity driven and therefore show a positive attitude towards new technologies.
- The introduction of ACE in public space did not leave the people untouched (e.g. ACE triggered a lot of conversation), an indicator for a successful breaching situation.
- Children show most self-confidence and least shyness when using the robot.

10.7. Iterative Design of the Remote Control by Means of Heuristic Evaluation

- The methodological approach was valuable because of non robotic experts acting as evaluators as they were not prejudiced of prior knowledge in the field of human robot interaction. Due to the fact of that design expert were participating it was possible to

get results of how usable and intuitive the remote interface was and should be. Firstly, this iterative approach appeared to be very useful and acceptable in order to design an interface with the objective of usability and intuitive use. Secondly, this technique proved to be very effective since problems in the interface could be identified in an early stage of design and therefore can keep the costs of the interface at a minimum.

- By means of the evaluation process it was found out that grave usability problems were caused because of the lack of visibility of system status, the match between system and real world and the flexibility and efficiency of use. For example it was not possible to get information of the position of the head while using the interface.
- Due to the effectiveness of the evaluation process a further evaluation of the resulted interface design should be conducted. Results of that evaluation then could show if the design of the interface is heading in a direction where usability, effectiveness and intuitive use is well reflected.

11. Summary and Outlook

This deliverable presented the study setting, procedure and results of 8 different evaluation studies conducted in the framework of the ROBOT@CWE project. All these studies were based on the theoretical and methodological USUS evaluation framework (see D1.3@M6 and Weiss *et al.* 2009). First insights on usability, social acceptance, user experience and societal impact could be provided. Furthermore, a comparative benchmarking of the different scenario sectors was presented. The chapter on “Lessons learned and recommendations” provided an overview how the findings gained in the first two years will inform the set-up and design of the integrated scenario for the final evaluation study at CNRS (Tsukuba, Japan). D4.6@M36 will include the results of the following activities which are planned for the third year of the ROBOT@CWE project:

- Online survey on user experience and social acceptance to increase the sample size
- Expert interviews on societal impact to assess the societal impact from the industrial point of view
- Standardized survey on societal impact for employees at DRAGADOS
- Cognitive walkthrough through the videos of all the user studies to gain more insights on usability, especially learnability
- User study on the haptic augmented simulation of the human-robot collaboration scenario with HRP-2 (as pre- study for the final demonstrator)
- User study of the final demonstrator (conducted at CNRS, Tsukuba, Japan)

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13. ANNEX

Annex A: Discussion Guideline for Focus Group

(1) What are you feeling now, immediately after watching the video?

- *Which ideas, attributes, feelings come into your mind?*
- *What would you feel if you had to collaborate with the robot?*

Please try to write these ideas and feelings in keywords down on the post-its and then put the post-its on the flip-chart!

(2) How would you describe/imagine the collaboration with a robot like the one in the video?

- *Which influences would the robot have on the working atmosphere (change/improvement/aggravation)?*
- *Where would you like to collaborate with such a robot? (household/at work...)?*
- *How easy or difficult is the collaboration with such a robot and why?*

(3) Concerning trust and security when collaborating with such a robot – how would you describe these aspects?

- *Would you believe that you are able to collaborate with the robot?*
- *How (high) would you estimate the competence of the robot?*
- *Could you rely on the robot?*
- *Do you think the collaboration is safe?*
- *Can you imagine possible difficulties when collaborating with the robot?*
- *What would be possible advantages of collaboration?*
- *What would be possible disadvantages of collaboration?*
- *Would you fear that the robot gets out of control?*

(4) What do you think – would previous knowledge about robots and their functioning be necessary for a successful collaboration with the robot? Why/why not?

- *Do you think that a substantial introduction is necessary for collaboration with the robot?*

- *Do you think that there would be a need for help from other working colleagues (technicians, ...) when working together with the robot?*
- *Is there a need for technicians in cases of problems?*

(5) *Would you refer to the robot rather as an equal working colleague or as a tool?*

- *Why?*
- *In which cases / under which circumstances?*

(6) *Would you consider the behavior of the robot as social? Why/why not?*

- *Do you think that the robot has adequately reacted to the commands of the involved persons? Why?*
- *Would you like that robots behave socially at the workplace? Why?*

(7) *How would you design the robot presented in the video so that it is best-suited for the task? Please try to build together the parts (together in the group) you see in front of you for your ideal robot!*

Annex B: Questionnaires

UX- Questionnaire

	Absolutely disagree						Absolutely agree
I liked the size of the robot.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Interacting with the robot was fun.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
When talking to the robot, I felt like talking to a human.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I was happy when the robot understood my commands.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I think that the robot is vulnerable to hackers.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I could interact with the robot like I interact with other humans.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I was disappointed if the robot did not understand my commands.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I liked that the robot looked similar to a human.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I hesitated to use the robot for fear of making errors that will harm me.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
When working with the robot I perceived it as working in a team.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I perceived the robot as a social actor	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I liked that the robot has human like features: face, ears, eyes, etc.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

I feared to use the robot, as an error might harm the robot.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I liked that the robot detected my face.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I felt good when interacting with the robot.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I liked the physical co-location of the robot.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I perceived that the robot is intelligent	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I was angry if the robot did not understand my commands	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I liked the design of the robot.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I enjoyed talking with the robot	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The robot could become a companion for me.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I felt secure when working with the robot.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I felt afraid of the robot.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I liked that the robot understood my commands	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I perceived the robot as safe.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

SoAc-Questionnaire

	Strongly agree	Agree	undecided	Disagree	Strongly disagree	Do not know
If I use robots, I will increase the chances of success in my job.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Deadline pressure would make my success with robots impossible.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would not like to imagine a world without the use of robots.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It is not necessary to use much technology in our daily work life.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
There will be enough training material to facilitate interactions with robots.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Robots will facilitate tasks which are now burdensome.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I have the necessary knowledge to use robots.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Robots and humans will form a good team.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The interaction with robots feels like give and take.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It would feel good to have a robot close to me.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The interaction with robots will be mutual.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I will find robots useful in my job.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Robots will be integral parts of our society.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Learning to operate robots is probably difficult.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I do not have the necessary resources to use robots.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

	Strongly agree	Agree	undecided	Disagree	Strongly disagree	Do not know
The interaction with robots will be clearly understandable.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I will not like to work with robots.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Efforts to solve tasks with robots in a collaborating way will be immense.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Using a robot will be a bad idea.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I feel a special connection to the robot.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It will be easy to use robots.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It will be easy for me to become skillful at using robots.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I could not complete a job or task using robots if no one was with me to tell me what to do.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I feel interdependent towards robots.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Robots would make work more interesting.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I could imagine to take a robot into my heart.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
If problems occur while I use robots, there will be persons who are able to help me.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Robots will have their place in our daily work lives.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Without support I will definitely get stuck.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I can imagine that I will care for the wellbeing of a robot.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Working with robots will be fun.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I will not be able to complete a task using robots at all.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Using robots will increase my productivity.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Robots will make my job easier.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Robots can play a similar role as human colleagues.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I can handle all problems without help.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It's fine for me, if robots belong to my work group.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I will be motivated to use robots in my daily work life.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Using robots will enable me to accomplish tasks faster.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I am afraid of using robots in my daily work life.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2 ACE Studies Questionnaires

Performance Expectancy (PE) Effort expectancy (EE) Attitude toward using technology (AT) Self efficacy (SE) Forms of grouping (G) Attachment (A) Reciprocity (R) Cultural Context (C) Embodiment (E)

Beim Reden mit dem Roboter fühle ich mich unwohl. Voll und ganz	Überhaupt nicht	SE
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<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Dieser Roboter wäre nützlich für mich. Voll und ganz	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Überhaupt nicht <input type="checkbox"/>	PE
Der Roboter könnte mir bei der Erledigung von Aufgaben helfen. Voll und ganz	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Überhaupt nicht <input type="checkbox"/>	PE
Ich könnte den Roboter per Sprache steuern. Voll und ganz	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Überhaupt nicht <input type="checkbox"/>	EE
Ich glaube, der Roboter ist einfach zu benutzen. Voll und ganz	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Überhaupt nicht <input type="checkbox"/>	EE
Viele Leute würden es toll finden, wenn ich einen solchen Roboter hätte. Voll und ganz	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Überhaupt nicht <input type="checkbox"/>	C
Ich betrachte den Roboter als ein soziales Wesen. Voll und ganz	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Überhaupt nicht <input type="checkbox"/>	R
Ich würde dem Roboter vertrauen, wenn er mir einen Ratschlag gibt. Voll und ganz	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Überhaupt nicht <input type="checkbox"/>	A
Ich würde den Ratschlag auch befolgen. Voll und ganz	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Überhaupt nicht <input type="checkbox"/>	A
Ich fühle mich von diesem Roboter verstanden. Voll und ganz	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Überhaupt nicht <input type="checkbox"/>	R
Ich finde es ist eine gute Idee den Roboter zu benutzen. Voll und ganz	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Überhaupt nicht <input type="checkbox"/>	AT
Ich könnte ohne Hilfe mit dem Roboter arbeiten. Voll und ganz	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Überhaupt nicht <input type="checkbox"/>	SE
Ich könnte mit dem Roboter arbeiten, wenn ich jemanden um Hilfe bitten könnte. Voll und ganz	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Überhaupt nicht <input type="checkbox"/>	SE
Ich könnte mit dem Roboter arbeiten, wenn ich ein gutes Benutzerhandbuch hätte. Voll und ganz	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Überhaupt nicht <input type="checkbox"/>	SE
Ich fühle mich in der Gegenwart dieses Roboters wohl. Voll und ganz					Überhaupt nicht	G

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Ich fürchte, beim Gebrauch des Roboters Fehler zu machen oder etwas kaputt zu machen.					
Voll und ganz				Überhaupt nicht	AT
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	