SIXTH FRAMEWORK PROGRAMME
PRIORITY 2

Specific Targeted Research Project

ROBOT@CWE

Advanced robotic systems in future collaborative working environments

Contract Number 034002

Deliverable 4.6@M36:
User evaluation report

Version	1.2
Status	Final
Date	11-11-2009

Deliverable Administration & Summary						
Deliverable	No.	Name				
	D4.6	User evaluation report				
Workpackage	No.	Name				
	WP4	*Prototypes and evaluation*				
Task	No.	Name	Description from DOW			
	T4.4	*Usability, user experience and impact evaluation*	All proof-of-concepts and the building experiment will be evaluated by the human science partners from the usability, user experience and social impact viewpoints. Based on the resulting style guides and recommendations from the previous WP, the prototypes will be evaluated in scenario-based user tests concerning usability and user experience aspects. Interviews and questionnaires will allow the evaluation of social impacts within and beyond the organisational context.			
Status	Draft		Due	M36	Date	2009-10-31
Author(s)	Weiss, A., Wurhofer, D. Igelsböck, J., Buchner, R., Förster, F., Michael Lankes, Tscheligi, M.					
Editor	Weiss, A. (PLUS)					
Comments						
Document workflow						
Draft version	Astrid Weiss (PLUS)				Date	2009-11-06
First revision	Jeremi Gancet (SAS)				Date	2099-11-10
Final Revision	Kheddar (CNRS)				Date	2009-11-11
Submitted	Kheddar (CNRS)				Date	2009-11-11

Document history			
Version	Date	Editor(s)	Description
1.0	06.11.2009	Weiss, A. (PLUS)	Draft Document
1.1	10.11.2009	Gancet, J. (SAS)	Revision
1.2	11.11.2009	Kheddar, A. (CNRS)	Revision
1.2	11.11.2009	Kheddar, A. (CNRS)	Submitted

Dissemination level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

Overview on Abbreviations

ATT	Attitude Towards Robots
CHI	Computer Human Interaction
EE	Effort Expectancy
EMB	Embodiment
E	Emotion
EU	European Union
EURON	EUropean RObotics research Network
FS	Feeling of Security
GUI	Graphical User Interface
ID	Identification
HCI	Human Computer Interaction
HOP	Human-Oriented Perception
HQI	Hedonic Quality - Identity
HQ-S	Hedonic Quality – Stimulation scale
HRI	Human Robot Interaction
HR interface	Human Robot interface
HRV	Heart Rate Variability
LSD	Least Significant Difference
NA	Negative Affect
NARS	Negative Attitude towards Robot Scale
OG	Human operator located in Germany
OJ	Human operator located in Japan
PA	Positive Affect
PANAS	Positive Affect Negative Affect Scale
PC	Perceived Competence
PE	Performance Expectancy
PQ	Pragmatic Quality
RE	Relationship Expectancy
SI	Social Impact
SI1	Societal impact factor 1: Quality of life, health and security
SI2	Societal impact factor 2: Working conditions and employment
SI3	Societal impact factor 3: Education
SI4	Societal impact factor 4: Cultural Context
SoAc	Social Acceptance
SD	Standard deviation
SE	Standard error
SUS	System Usability Scale
TP	Test participant
USUS	Usability, social acceptance, user experience and societal impact factors of evaluation
UX	User Experience
WOz	Wizard-of-Oz

Executive Summary

This deliverable presents the study setting, procedure and results of 7 different evaluation studies conducted in the third year of the ROBOT@CWE project. For these studies, the USUS evaluation framework (see D1.3@M6 and Weiss et al., 2009) provided the theoretical and methodological basis. From the results of the evaluation studies of the third year as well as from previous study results, important conclusions on usability, social acceptance, user experience and societal impact were drawn. By conducting an online questionnaire with a large sample, important insights could be gained for the factors user experience and social acceptance. Expert as well as non-expert interviews revealed important information about the imaginations of a future society with robots. These insights were used as input for a questionnaire on societal impact. A mixed reality simulation of human-robot collaboration was conducted in order to investigate human-robot collaboration in a virtual world. Furthermore, expert evaluations were conducted in order to iterate and improve the design of a remote control as well as for identifying problems concerning learnability of two human-robot interaction use cases. Finally, the evaluation of the final demonstration with HRP-2 completed our activities.

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). The focus of this deliverable lies on the final report on usability, social acceptance, user experience and societal impact, which contributes to the project by:

1. Evaluating the different platforms and the final integrated scenarios used in the ROBOT@CWE project in terms of usability, social acceptance, user experience and societal impact by means of several evaluation studies.
2. Defining the important influence factors based on these evaluation studies for the integrated scenarios 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 to answer the overall evaluation questions presented in D1.3@M6. This deliverable is subsequent to deliverable D3.4-7@M30 and presents all additional evaluation activities in WP3 and WP4 and the evaluation results of the final integrate scenario.

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 also by 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 all evaluation studies conducted in the third period of the ROBOT@CWE project in WP 3 and WP4. The main focus is put on the evaluation of the HRP-2 final demonstrator and the societal impact assessments.
The evaluation goals of the user studies can be found in D1.3@M6. User studies which were conducted until the end of the second period of the project as well as preliminary insights are presented in D3.4-7@M30. Furthermore, methodological considerations can be found in chapter 3 of D3.4-7@M30. User studies conducted during the third period of the project are presented in the deliverable at hand (D4.6-7@M36). Within the ROBOT@CWE project we used an interdisciplinary method mix, resulting in a broad spectrum of methods for addressing the different evaluation factors. Table 1 gives an overview of the methods used for the evaluations as well as the factors addressed by these methods in the third period of the ROBOT@CWE project. In the present deliverable, each user study is presented with regard to the study setting, the instruments used, the procedure of the study as well as to the results. The interpretation of the results is done within the conclusion chapter (chapter 5.). The conclusions comprise the results of all user studies of the project (presented in D3.4-7@M30 and D4.6-7@M36), answering the main guiding research questions provided in D1.3@M6 with regard to the factors of the USUS evaluation framework. The Annex contains all new materials used for the user studies of the third period. Older materials can be found in the Annex of D1.3@M6 and D3.4-7@M30. Moreover, detailed results on the heuristic evaluation of the tele-operator interface conducted by PLUS can be found in D3.8@M36.

	Usability	**Social Acceptance**	**User Experience**	**Societal Impact**
Expert interviews on societal impact of humanoid robots				X
Questionnaire on societal impact with DRAGADOS employees				X
Online Questionnaire on SoAC and UX in HRI		X	X	
Expert evaluation of remote control design (2nd iteration)	X			
Mixed reality simulation of human robot collaboration	X	X	X	X
User study final demonstration	X	X	X	X
Group-based cognitive walkthrough	X			

Table 1: Methods used and factors addressed

3. Evaluation Studies in WP3

This chapter presents the evaluation studies conducted within WP3. These studies comprise expert interviews on the societal impact of humanoid robots, a questionnaire on societal impact, an online questionnaire on UX and SoAc, as well as a heuristic evaluation.

3.1. Expert Interviews on Societal Impact of Humanoid Robots

3.1.1 Study Setting

In order to find out how experts imagine a future society with robots, expert interviews with robotic engineers from the project partners DRAGADOS and SAS were conducted. The expert interviews at DRAGADOS took place in September 2008 in Madrid, Spain. The interviews were carried out with two robotic engineers from DRAGADOS working in the field of robotic automation for factories. The interviews at SAS took place in March 2009 in Zaventem, Belgium, involving four robotic engineers for space applications. Altogether, six experts in the field of robotics (one female, five male) were interviewed. All interviews were conducted in English.

Within the expert interviews, the following research question was investigated:

- Overall, how do experts imagine the future societal impact of robots with regard to the four factors of societal impact?

Additionally, information on the following issues was collected:

- Which repeated key aspects of future human-robot relationships are mentioned by the experts?
- What constitutes a robot and which attributes and tasks do the participants assign to a robot?

3.1.2 Instruments

Semi-structured expert interviews were conducted for investigating the experts' imagination of a future society with robots. In a semi-structured interview, the interviewer has a basic set of questions but can go further or bring up new questions in response to the participants' answers during the interview. The interview guideline (see Annex section 7.3.) for the expert interviews consisted of about 25 questions. All questions were based on the four indicators defined for societal impact (abbreviated as SI; see D1.3 for details): Quality of life, health and security (SI 1); Working conditions and employment (SI 2); Education (SI 3); Cultural Context (SI 4). The interview guidelines for the SAS interviews were set up in accordance with the Delphi Approach. The Delphi Approach is a special type of expert interview where several rounds of interviews are conducted. The guidelines of each round are based on the results of the previous study. This procedure should result in a common expert opinion on a topic. Thus, the SAS interview guidelines were composed on the basis of the results of the DRAGADOS interviews.

Additionally, the experts were handed out a social acceptance questionnaire (see D3.4-7 for details) and the NARS questionnaire (see D3.4-7 for details), as well a short demographical questionnaire.

3.1.3 Procedure

The expert interviews lasted about one and a half hour. In order not to interrupt the flow and leave the decision on the degree of importance for the addressed aspects of societal impact to the experts, the interviewer adapted the order of the questions according to the issues introduced by the experts. After the interview, three additional questionnaires (see section 3.1.2) had to be filled in by the experts.

3.1.4 Overview on Results

The insights into future impact were grouped according to our four indicators of societal impact and are summarized and presented in the table below (Table 2). Detailed results can be found in the Annex, chapter 7.4.
.

SI Indicator	Experts' Opinion
Quality of life, health and security of citizens (SI 1)	• **Safety is a critical issue in human-robot collaboration** According to the experts, the most important topic when working together with robots is safety. Robots would represent a special risk, and therefore safety issues have to be considered particularly. • **No negative health effects of robots** The experts think that robots will not have any negative effects on human health. One expert even thinks that robots will increase life expectancy. The other expert points out that robots negatively affect communication, however, will not have negative influences on health. • **Various application fields for robots** One of the experts thinks that robots will mainly be slaves. The experts see robots in various fields like elderly care, service jobs and education.
Working condition and employment (SI 2)	• **The introduction of robots mainly affects low skilled people** The experts state out that societal changes due to the introduction of robots in the workplace are on the hand as there will be increasing unemployment. The first workplaces where robots will enter will be those of low level educated people doing physical exhausting work. Thus, people with low professional qualifications will be mainly affected by the introduction of robots in collaborative environments. • **The first applications of robots will be for "3D" jobs** The experts see robots at first in jobs which require only basic skills and which are dangerous, dirty and dull (= 3D). • **No changes in income** Both experts indicate that there will be no changes in people's

	income due to the introduction of robots at the workplace. • **A step by step introduction of robots at collaborative working environments avoids problems** There will not be any problems or conflicts due to the introduction of robots in collaborative environments if this is done step by step. There will be no social problems when robots are integrated in the working place step by step. • **Human-robot collaboration will convey new kinds of jobs** According to the experts, with an increased number of collaborative robots, new types of jobs will evolve, for example maintenance of robots, instructor for robot. • **The introduction of robots is a cost-benefit question** The introduction of robots depends on the costs; if robots do the same work for less money, they will be introduced. Thus, the introduction of robots is a benefit-cost question. The objectives of an industrial robot are increasing productivity, decreasing the costs and giving workers more security by carrying out dangerous tasks instead of them. Therefore, three conditions have to be fulfilled before a robot replaces a human: money, maintenance and (human) controllers of the robot. Factors that stop or retain the usage of robots are high costs of introduction, limited flexibility of robots and the need for maintenance of robots.
Education (SI 3)	• **Education becomes more important** One of the experts points out that with the introduction of robots in the workplace, education becomes more important. Higher educated people will be preferred at the job market. • **No need to change the education system** According to the experts' opinion, there is no need to change the education system or to teach ethics in school when robots are introduced into working life. A reason for that is that children will playfully learn how to use new technologies. • **Employee training and specializations of universities** One of the experts thinks that for collaborating with robots, training of the employees is necessary. The other expert thinks that there will be changes on university level, as more universities will specialize in robotics. • **Educational level influences acceptance**

	In the interviews, the experts pointed out that the educational level of a person influences his/her acceptance of robots. Low education would imply low acceptance of robots, as lower educated people could be replaced by robots and therefore will probably have a negative attitude towards robots.
Cultural context (SI 4)	• **Change in value system** One of the experts indicates that the introduction of robots will change the value system steadily. He points out that a change which is too fast will lead to problems. • **Culture does not limit the use of robots** The experts indicate that culture does not limit the use of robots in any ways. Cultural aspects like religion are less important, the most influential factor for taking robots into use is technology and money. If people think that they benefit from a new technology/robot, they will buy it and take it into use. With other words, if people think something is useful, they will use it.

Table 2: Overview on results from expert interviews with DRAGADOS employees

3.1.4.1 Results of follow-up Interviews with Experts from SAS

The results into societal impact of robots, grouped according to our four indicators of societal impact. The table presented below (Table 3) presents a summary of the most important results from the expert interviews with SAS employees according to the societal impact factors. Detailed results of the interviews can be found in the Annex, chapter 7.6.

SI Indicator	**Experts' Opinion**
Quality of life, health and security of citizens (SI 1)	• **Robots will mainly have positive impacts on quality of life** According to the experts' opinion, robots have more positive than negative effects on the humans' quality of life. The experts indicate that robots will do housekeeping tasks and have a positive effect on health care. However, some of the experts also point out possible negative effects, like for example that people get lazier when robots take over tasks. • **Security has to be ensured in human-robot interaction** The experts think that security is a critical issue which mainly affects the work context. Therefore, the experts advise supervision by human controllers and security measures. • **Robots will never replace human beings** Experts indicate that robots will not take over the role of human beings and will never be a substitute for a human relationship.

	However, there is a risk that robots amplify social isolation.
Working condition and employment (SI 2)	• **There will be no negative effects due to an introduction of robots in the workplace** Experts foresee a positive effect on the working conditions due to the introduction of robots. A lot of new sophisticated jobs will be created, and people will engage more in education • **The main reasons for introducing robots at working environments is an increase in productivity** The experts indicate that robots are increasingly deployed in factories because of their gain in efficiency. • **Robots should be introduced step by step** In order not to overstrain workers, robots should be introduced in a working environment stepwise. Moreover, awareness that robots will not replace humans has to be created.
Education (SI 3)	• **Teaching of "robotics" is not necessary** Experts think that there is no specific education for interacting with robots is needed. However, the experts assume that new (robotic) sciences will evolve on university level.
Cultural context (SI 4)	• **People's images of robotics are heavily influenced by science fiction media** Experts state out that the "typical" robotic image of everyday people comes from science fiction media. Moreover, the embodiment of the robot is mainly defined by culture, which can be seen when comparing the embodiment of European and Asian robots. • **European people are not ready for robots** Experts indicate that there will be more elaborated robots in the next ten years. However, European people will not accept that robots do more elaborated tasks, in contrast to Japan, where the acceptance of robots in working environments is much higher.

Table 3: Overview on results from interviews with experts from SAS

3.1.4.2 Overall Results on Expert Interviews about Societal Impact of Humanoid Robots

Valuable information on robotics and its societal impact and implications in the next 20 years was provided by the experts of DRAGADOS and SAS. Table 4 gives a summary on the most important findings of the expert interviews.

SI Indicator	Experts' Opinion
Quality of life, health	• **Safety & Security are the most critical issues in human-**

and security of citizens (SI 1)	**robot collaboration** • **Robots will not have any negative effects on humans' health** • **Robots will mainly have positive impacts on humans' quality of life** • **Robots will never replace human relationships**
Working condition and employment (SI 2)	• **Human-robot collaboration will convey new kinds of jobs** • **The introduction of robots at work will mainly affect low skilled people** • **The introduction of robots is a cost-benefit question** • **The main reason for introducing robots at collaborative working environments is an increase in productivity** • **Robots should be introduced in (collaborative) working environments step by step**
Education (SI 3)	• **There will be no need to change the education system with an increased deployment of robots** • **A person's educational level influences his/her acceptance of robots**
Cultural context (SI 4)	• **Cultural aspects are less important for taking robots into use** • **People's images of robotics are heavily influenced by science fiction media** • **European people will not accept more elaborated robots in (collaborative) working environments**

Table 4: Experts' view on the future societal impact of robots

The expert interviews also dealt with the question of how to define a robot and which tasks to assign. The following list deals with this question:

- **Definition of robots**
  Asking experts to define the term "robot" showed that there is no common sense on this issue. Some experts characterized a robot by tasks it is fulfilling. They indicated that a robot can be differentiated from a machine by its ability of multitasking or by a higher level of independence. Flexibility was also mentioned often for defining a robot.

- **Difference between human and robot**
  When the experts were asked to give criteria for distinction between humans and robots, the experts' answers were not homogeneous. All except one expert used attributes and capabilities to differentiate the robot from the human, for instance the human has a "huge capability of learning and is unpredictable in contrast to the robot", or "the human is as complex as a robot will never be". One expert defined the difference by the help of the components, stating: "the biological components the humans are made of are the difference", but also noted that future robotics will exceed this limitation as there are yet robots that make use of biological processes.

- **Type of work robots are capable of**
  Concerning the question of which kind of work robots are capable of, the experts were in disagreement. Some experts said that robots will be able to do everything, whereas some of the experts indicated that robots will do dirty, dangerous, and dull work, doubting that robots are appropriate as teachers or care takers of elderly because of ethical reasons. Furthermore, the experts assumed that robots will never be capable to fulfill creative work.

The expert interviews showed that there are certain aspects of future human-robot relationships which were mentioned repeatedly. These key aspects are the following:

- **Replacement**
  The experts foresee a replacement problem for very low skilled people who are now fulfilling boring and repetitive tasks. However, this replacement is not regarded negatively, as the experts are of the opinion that people will be better educated in future and as a consequence get more sophisticated jobs.

- **Competition**
  The experts did not see robots on the same level as humans and thus did not see robots as competitors of human workers. They stressed the strong need of human workers in future, referring to the social aspect of working.

- **Safety, Security, and Supervision**
  On the one hand, safety will increase by the employment of robots as they carry out dangerous tasks which otherwise had to be performed by humans. On the other hand, safety has to be ensured when collaborating with robots. Together with the term safety, risk was also often mentioned.

- **Cost – Benefit Assessment**
  The experts indicate that if a robot is affordable and accordingly advertised, it is supposed to be a success. Moreover, they stress the influence of the mass media (e.g. Hollywood-films) as well as advertisement, as they are affecting the humans' attitude towards robotics.

3.2. Questionnaire on Societal Impact with DRAGADOS Employees

3.2.1 Study Setting

In order to get insights on how employees of DRAGADOS estimate the future societal impact of robots, we developed a questionnaire. By means of this questionnaire, the following research question should be answered: "How do non-experts imagine the future societal impact of robots with regard to the four factors of societal impact?"
This questionnaire was based on the results of the societal impact interviews conducted with the participants in the user studies and the expert interviews. In June 2009, a Spanish version of this questionnaire was sent to ten employees of DRAGADOS (five male, five female) and filled in until the end of July 2009. The mean age of the participants was 35 years, with the youngest participant aged 26 and the oldest participant aged 51 years. Four of the participants had attended high school, and six had completed academic studies. The English version of the societal impact questionnaire can be found in Annex section 7.8.

3.2.2 Instruments

The societal impact questionnaire contained the following scales:

- Quality of life, health, and security (SI 1)
- Working conditions and employment (SI 2)
- Education (SI 3)
- Cultural context (SI 4)

These scales were chosen in accordance to our indicators defined for societal impact. Each scale included at least four items. Based on the analysis of the expert and non-expert interviews, the items were chosen. Overall, the questionnaire consisted of 25 questions. 20 of these questions were formulated as statements for the participants agreement had to be indicated on a five-point rating scale. The other five questions consisted of statements which the participants had to tick off if they agreed (four of these questions allowed multiple answers).

3.2.3 Procedure

In June 2009, the employees of DRAGADOS were sent a digital Spanish version of the societal impact questionnaire by e-mail. They had to fill in the questionnaire within one month. The filled in questionnaires were sent back at the end of July 2009 and analyzed by the researchers of PLUS in August 2009.

3.2.4 Overview of Results

Figure 1 gives an overview on the mean scores of the four scales of societal impact. A summary of the most important results, grouped according to the societal impact indicators addressed, is given in Table 5. More detailed results can be found in the Annex, chapter 7.7.

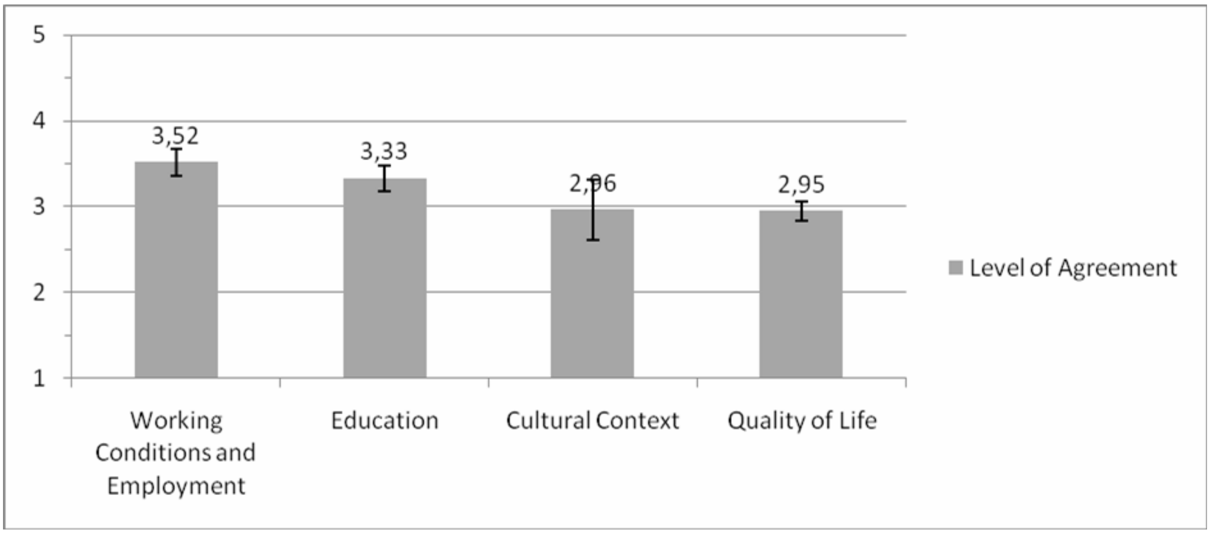

Figure 1: Mean scores for societal impact indicators

SI Indicator	Insights
Quality of life, health and security (SI 1)	• **Dichotomy on the future impact of robots on interpersonal relationships and health** The questions if robots lead to social isolation of people, have negative effects on communication and have a positive effect on

	health are answered controversially, meaning that as much people agree as disagree with these statements. Asking people directly if robots influence social relationships also shows dichotomy on this issue. • **Positive effects of robots on the quality of life** Most people were of the opinion that robots increase the well-being of humans as well as leisure time for humans. • **Indecision about security in human-robot collaboration** About one third of the participants indicate to be undecided if robots make life safer or if it is risky to collaborate with robots. However, most of the people who are not undecided about this issue state that robots make life safer and think that collaboration with robots is not risky.
Working conditions and employment (SI 2)	• **Effects on working life due to the introduction of robots on the workplace are rather seen as negative** Most of the participants think that robots in the workplace increase the competition between low-skilled people and lead to a higher unemployment rate among humans. Moreover, one third of the participants do not know if robots lead to a higher unemployment rate among humans. • **Robots are suited best for work that requires spatial organization and preciseness** Most participants indicate that robots are capable of work that requires spatial organization and preciseness. Coordination and memorization are also mentioned often. • **Robots are not capable for work that requires negotiation, persuasion, creativity, judgment or diplomacy** The capabilities negotiation, persuasion, creativity, judgment or diplomacy are not attributed to robots at all.
Education (SI 3)	• **Dichotomy on the question if robots raise the educational level of humans** Equally as many participants agree and disagree with the statement that robots raise the educational level of humans. • **Specific knowledge is needed for collaborating with robots** Most of the participants state that specific knowledge is required when collaborating with robots. However, concerning the question if additional knowledge is needed for interacting with robots in general, no clear tendency can be figured out. • **Growing up with robots eases the right handling of robots** The predominant majority of participants think that growing up

	with robots eases the right handling of robots; nobody disagrees with this statement. • **Robotic training lessons at work are needed** In general, all participants think that specific educational measures are needed for the collaboration of humans and robots. Particularly, robotic training lessons at work are a seen as a necessary educational measure for the collaboration of humans and robots.
Cultural context (SI 4)	• **Uncertainty on the question if robots could develop a momentum** Concerning the question if robots could develop a momentum, half of the participants indicated to be undecided or did not answer this question at all. This shows that there is great uncertainty about this issue. However, the biggest part of the participants who answered this question agreed with the statement that robots could develop a momentum. • **There is no risk that robots turn against humans** Most of the participants think that there is no risk that robots turn against humans. However, most participants agree with the statement that robots can hurt people. • **Creativity is the most important difference between humans and robots** Creativity is seen as the most important issue causing the difference between humans and robots. Biological components as well as the unpredictability of humans are also important factors for distinguishing humans from robots. • **Robots are mainly seen as tools in the future** Most participants think that robots will be tools. Many participants also see robots assistants or toys. • **Robots are not seen as future companions** Nobody of the participants thinks that robots will be companions for humans in a future society. • **Robots are typically seen as anthropomorphic** When asking participants what comes in their mind when they hear the term “robot”, most of them thinks of anthropomorphic robots. Zoomorphic robots are not associated with the term “robot” at all.

Table 5: Results from questionnaire on future societal impact of robots

3.3. Online Questionnaire on Social Acceptance and User Experience in HRI

3.3.1 Study Setting

To increase the sample size for investigating indicators influencing Social Acceptance and User Experience, an online video-based questionnaire was set up. The online questionnaire was distributed via e-mail, being available in four languages (German, English, French, Spanish). The Spanish and the French version of the questionnaire were translated by accredited translators. The English version of the online questionnaire can be found in the Annex, section 0

In total, 398 online questionnaires were filled in. Questionnaires with more than 10% of the questions missing or with suspect data patterns were filtered from the sample.

Altogether, participants from 37 different countries filled in the online questionnaire. Thereof, 83% were from the EU. The mean age of the participants was 29 years (SE: 0.438, n=395), with the youngest participant being 19 years and the oldest one being 66 years old. The number of male and female participants was almost uniformly distributed (53% male, 47% female).

Most of the participants had a university degree (60%). The other participants had finished highschool (39%). 1% of the participants had only finished obligatory school. 77% of the participants had no previous knowledge in the field of robotics or HRI, whereas 23% of the participants already worked or still works in the robotics field. One third of the participants (34%) already took part in an HRI experiment.

3.3.2 Instruments

The online questionnaire was set-up with the lime survey tool (www.limesurvey.org/). The items of the questionnaire were based on the previously developed UX and SoAc questionnaires (see D3.4-7@M30). For the UX questionnaire, suitable items were extracted, i.e. questions which could be answered by passively observing human-robot interaction via the videos. The questionnaire further comprised a short video (about 1.5 minutes). This video was either about HRP-2 or the HOAP-3 robot (extracted from the preliminary HRP-2 user study and the first HOAP-3 user study, see D3.4-7@M30). Each time the link of the online questionnaire was clicked on, one of the videos was allocated to the online questionnaire randomly.

This extraction process caused a strong reduction of the number of items of the questionnaires. All defined UX factors (embodiment, feeling of security, emotion, human-oriented perception, co-experience) as well as all defined SoAc factors (performance expectancy, effort expectancy, attitude towards robots, forms of grouping, feeling of Reciprocity, Attachment, Self Efficacy, Facilitating Conditions) were covered by the online questionnaire. In addition to the items on UX and SoAc, the participants had to answer a few socio-demographic questions.

3.3.3 Procedure

The link of the online questionnaire was sent out via three scientific mailing lists (CHI-announcement, robotics worldwide, and EURON) as well as via the ROBOT@CWE mailing list, with the request to forward it. The run time of the online questionnaire was about two months, starting in March 2009 and ending in May 2009.

After selecting the link to the online questionnaire, the procedure for filling in the questionnaire was the following: First, the participants were presented a short movie about interaction with HRP-2 or HOAP-3. Then they had to answer questions on UX and SoAc in relation to the presented video. Finally, they had to answer some demographic questions.

3.3.4 Overview of Results

3.3.4.1 Description and outcome of FACTOR ANALYSIS

The online questionnaire included the following pre-defined indicators of UX: embodiment, feeling of security, emotion, human-oriented perception and co-experience. In total, there were 15 items in the online questionnaire which covered these indicators. SoAc was defined by the pre-defined indicators performance expectancy, effort expectancy, attitude, forms of grouping, feeling of reciprocity, attachment, self efficacy and facilitating conditions. Altogether, 47 items covered these indicators in the online questionnaire.

In order to define the dimensionality for SoAc and UX and to reduce the pre-defined SoAc and UX indicators to a smaller number of independent factors, a factor analysis of the data gathered from the filled in questionnaires was conducted. Thus, the factor analysis informs about which factors (indicators) from the theoretical factor indicator model (see D1.3@M6) are relevant for UX and SoAc. The results of the factor analysis are then interpreted in conjunction with the theoretical knowledge on UX and SoAc indicators, resulting in an updated collection of indicators (factors) characterizing UX and SoAc.

Based on the data of the 15 UX and the 47 SoAc items, factors were extracted using Maximum Likelihood method. In conjunction with the plots of the scree test (see Figure 2), four factors of UX and five factors of SoAc were rotated using Varimax rotation with Kaiser Normalization.

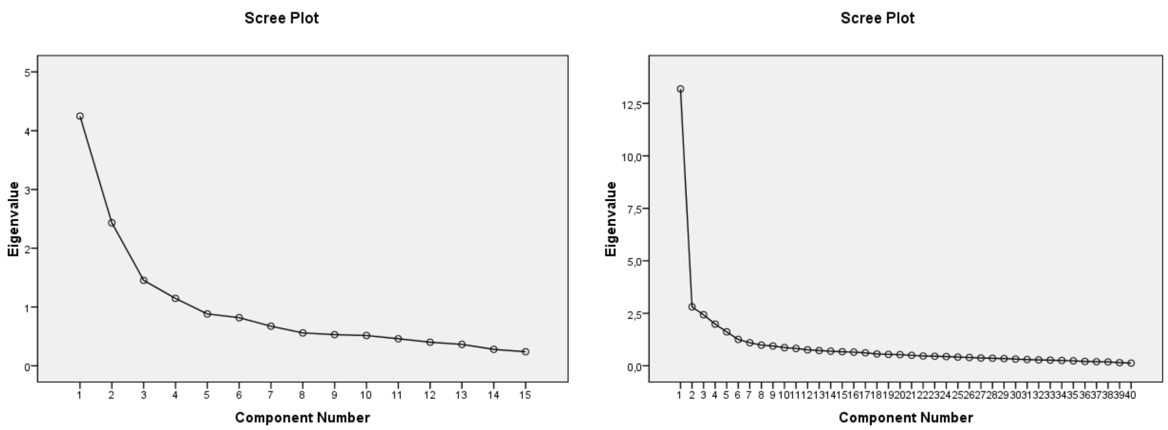

Figure 2: Scree plots for user experience (UX) and social acceptance (SoAc)

The rotated solution for UX (see Table 6) was interpreted as the following four indicators (factors) of UX: embodiment (EMB), feeling of security (FS), human-oriented perception (HOP) and emotion (E). Thereof, embodiment explains 28%, feeling of security 16%, human-oriented perception 10% and emotion 8% of the total variance.
The rotated solution of SoAc (see Table 7) resulted in the following five indicators (factors) of SoAc: performance expectancy (PE), effort expectancy (EE), relationship expectancy (RE), perceived competence (PC) and attitude towards robots (ATT). Thereof, performance expectancy explains 33%, effort expectancy 7%, relationship expectancy 6%, perceived competence 5% and attitude towards robots 4% of the total variance.

By means of the factor analysis, the number of indicators accounting for UX could be reduced from five to four, and for SoAc from eight to five indicators. Based on the new UX and SoAc indicators, the data of the online questionnaire was analyzed.

The following tables present the results derived from the factor analysis, including the statements used in the questionnaire and the originally assumed factors (indicators). For more details on the original factors (indicators) see D3.4-7@M30.

Original Factor	Item	Resulting Factor			
		EMB	FS	HOP	E
EMB	I liked the size of the robot.	**0,503**	-0,095	0,246	0,007
EMB	I liked that the robot looked similar to a human.	**0,793**	-0,080	0,194	-0,077
EMB	I liked that the robot has human like features: e.g. face, ears, eyes etc.	**0,873**	-0,027	0,175	-0,064
EMB	I liked the design of the robot.	**0,598**	-0,150	0,273	-0,061
FS*	I think that the robot is vulnerable to hackers.	0,008	**0,454**	-0,058	-0,080
FS*	I hesitated to use the robot for fear of making errors that will harm me.	-0,023	**0,686**	-0,107	-0,069
FS*	I feared to use the robot as an error might harm the robot.	-0,039	**0,658**	0,287	-0,038
FS	I perceived the robot as safe.	-0,226	**0,553**	-0,415	-0,019
HOP	I perceived the robot as a social actor.	0,355	-0,074	**0,518**	0,012
HOP	I perceived that the robot is intelligent.	0,229	0,035	**0,602**	-0,052
C	The robot could become a companion for me.	0,288	-0,137	**0,487**	0,045
E	I would be disappointed if the robot did not understand my commands.	-0,150	-0,085	-0,101	**0,614**
E	I were angry if the robot did not understand my commands.	0,056	-0,145	0,131	**0,979**
	Deleted Items:				
FS	I would feel secure when working with the robot.	0,210	-0,581	0,410	-0,005
E	I would feel afraid of the robot.	0,124	-0,594	0,028	0,061

* Reverse items

Table 6: Rotated factor matrix for user experience (UX)

Original Factor	Item	Resulting Factor				
		PE	ATT	RE	EE	PC
PE	The deployment of robots will increase my chances of success in my job.	**0,580**	0,314	0,109	-0,012	0,192
PE	I will solve tasks faster using robots.	**0,694**	0,100	0,014	0,218	-0,024
PE	Robots will make my tasks easier.	**0,796**	0,138	0,144	0,179	0,042
PE	Robots will facilitate burdensome tasks we have now.	**0,487**	0,282	0,067	0,170	0,029
FG	Robots and humans will make a good team.	**0,477**	0,418	0,320	0,225	0,132
PE	I would find robots in my job useful.	**0,656**	0,323	0,187	0,146	0,232
PE	The utilisation of robots will increase my productivity.	**0,768**	0,272	0,139	0,214	0,111
ATT	Robots will make work more interesting.	0,483	**0,462**	0,263	0,124	0,094
ATT*	I would not like to work together with robots.	0,342	**0,593**	0,189	0,141	0,205
ATT*	Using robots is a bad idea.	0,272	**0,649**	0,114	0,204	0,153
ATT*	I would be afraid to employ robots at work.	0,142	**0,564**	0,038	0,367	0,225

ATT	Working with robots would be fun.	0,284	**0,663**	0,320	0,228	0,209
A	I would not like to imagine a world in which robots were not used.	0,159	**0,350**	0,199	0,092	0,213
FG	I would like to collaborate with robots.	0,406	**0,715**	0,341	0,208	0,149
FR	I can imagine that I will care for the wellbeing of a robot.	0,129	0,503	**0,404**	0,110	0,237
A	I can imagine to take a robot into my heart.	0,000	0,309	**0,733**	0,029	0,033
FG	Robots will have a similar importance as human colleagues.	0,201	0,039	**0,655**	0,051	0,012
A	It would feel good if a robot was near me.	0,221	0,383	**0,590**	0,132	0,115
FR	The interaction with robots will be a mutual experience.	0,309	0,008	**0,459**	0,166	0,136
A	I can imagine building a special relationsship with robots.	0,055	0,294	**0,798**	-0,001	0,042
FR	The relationship with robots will be based on the principle of give and take.	0,059	0,049	**0,518**	0,042	0,061
FG	Robots will be an important part of our society.	0,402	0,136	**0,413**	0,186	0,079
EE	It will be easy for me to become skillful in dealing with robots.	0,137	0,329	0,207	**0,336**	0,302
EE	Interacting with robots will be easy to understand.	0,208	0,059	0,152	**0,784**	0,094
EE*	It would be difficult to learn how to handle robots.	0,058	0,048	0,015	**0,654**	0,173
EE	It will be easy to use robots.	0,203	0,140	0,111	**0,758**	0,148
EE*	Efforts to solve tasks together with robots will be a huge undertaking.	0,108	0,141	-0,018	**0,489**	0,070
FC	There will be enough information material available to help simplify the interaction with robots.	0,191	0,228	0,150	**0,506**	0,065
SE*	I could not solve a task with the help of robots if no one was there to tell me what to do.	-0,065	0,110	0,032	0,222	**0,424**
SE	I could solve all problems which occurred during the interaction on my own.	0,085	0,079	0,150	0,118	**0,600**
FC	I have the necessary knowledge to handle robots.	0,269	0,225	0,188	0,028	**0,811**
SE*	When a problem occurrs with robots, I would not be able to continue with my work without help.	0,021	0,102	-0,037	0,111	**0,549**
FC*	I do not have the necessary abilities to handle robots.	0,149	0,139	0,050	0,052	**0,685**
	Deleted Items:					
FG	Robots will be part of our everyday work.	0,483	0,274	0,315	0,188	0,073
SE*	I could not be successful while working with robots under time pressure.	0,129	0,191	0,050	0,227	0,149
FR	Humans and robots will be interdependent.	0,403	-0,003	0,313	0,048	0,093
SE*	I will never be able to solve a task together with a robot.	0,280	0,319	0,101	0,325	0,145
FC	I would be motivated to integrate robots in my daily workday.	0,472	0,562	0,268	0,269	0,197
FC	If problems with robots occur there would be persons who could help me.	0,126	0,264	0,048	0,343	-0,012
ATT*	I do not think it is necessary to employ robots in daily working life.	0,369	0,294	0,007	0,230	0,043

* Reverse items

Table 7: Rotated factor matrix for social acceptance (SoAc)

3.3.4.2 Overview on Results of Online Questionnaire

In the following, the most important results of the analysis of the online questionnaire are presented.

3.3.4.2.1 Average values of UX indicators

Concerning the average scores of the UX indicators of the online questionnaire (scale ranges from 1-“absolutely disagree” to 7-“absolutely agree”), embodiment received the highest score (mean: 4.43, SE: 0.08). Next comes emotion (mean: 3.54, SE: 0.09) and feeling of security (mean: 3.53, SE: 0.07). With a mean of 2.83 (SE: 0.07), the indicator human oriented perception had the lowest score.

3.3.4.2.2 Average values of SoAc indicators

Regarding the indicators of SoAc (scale ranging from 1-“absolutely disagree” to 5-“absolutely agree”), effort expectancy received the highest average score (mean: 3.51, SE: 0.04), followed by the indicators attitude towards technology (mean: 3.38, SE: 0.05) and performance expectancy (mean: 3.21, SE: 0.05). Relationship expectancy is rated lowest (mean: 2.45, SE: 0.04), followed by perceived competence (mean: 3.20, SE: 0.05).

3.3.4.2.3 EU versus non-EU citizens

There are some significant differences on how EU citizens experience interaction with the HOAP-3 or the HRP-2 robot compared to non-EU citizens (see Figure 3). Non-EU citizens have rated human-oriented perception and embodiment significantly higher ($p=0.014$ and $p=0.000$) than EU citizens. This means that non-EU citizens experience the robot (either HOAP-3 or HRP-2) more human-like and rate the robot’s embodiment more positive than EU citizens.

Regarding the UX indicators emotion and feeling of security, no significant differences between EU and non-EU citizens could be found.

Significant high differences between EU and non-EU citizens ($p<0.01$) could also be found for social acceptance of robots (see Figure 4). This difference is significantly high for the indicators performance expectancy ($p=0.000$), attitude towards robots ($p=0.000$) and relationship expectancy ($p=0.000$). A significant difference ($p<0.05$) could also be found for the indicator perceived competence ($p=0.041$). Non-EU citizens rated these factors higher than EU citizens, meaning that non-EU citizens expect a higher increase in performance when collaborating with the robot (either HOAP-3 or HRP-2), have a more positive attitude towards robots, expect a more positive relationship with robots and feel more competent concerning human-robot interaction.

Regarding the SoAc indicator effort expectancy, no significant differences could be found.

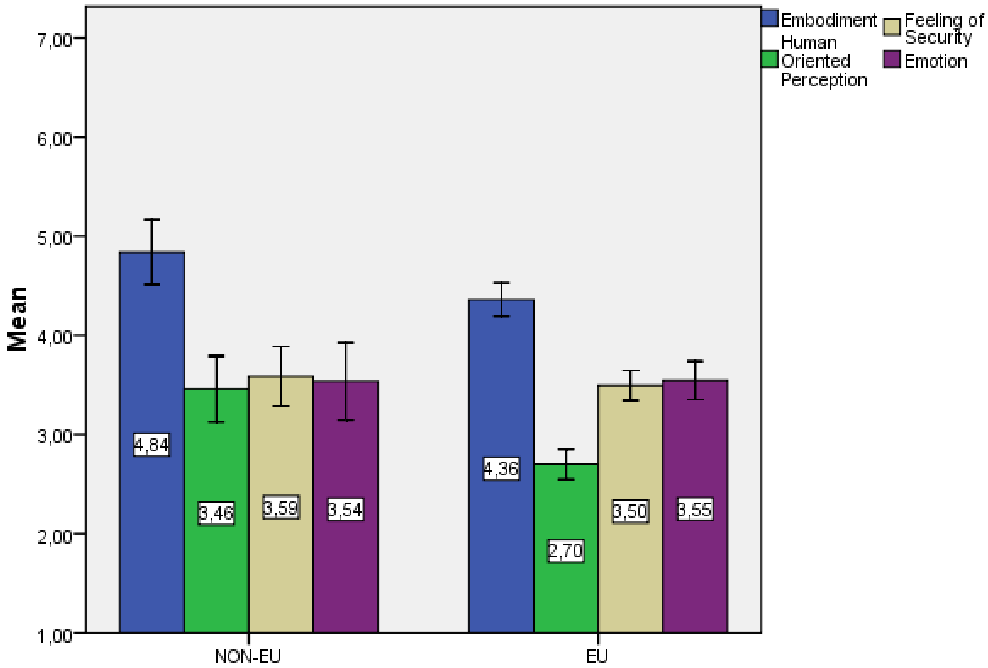

Figure 3: User experience – non-EU citizens and EU citizens

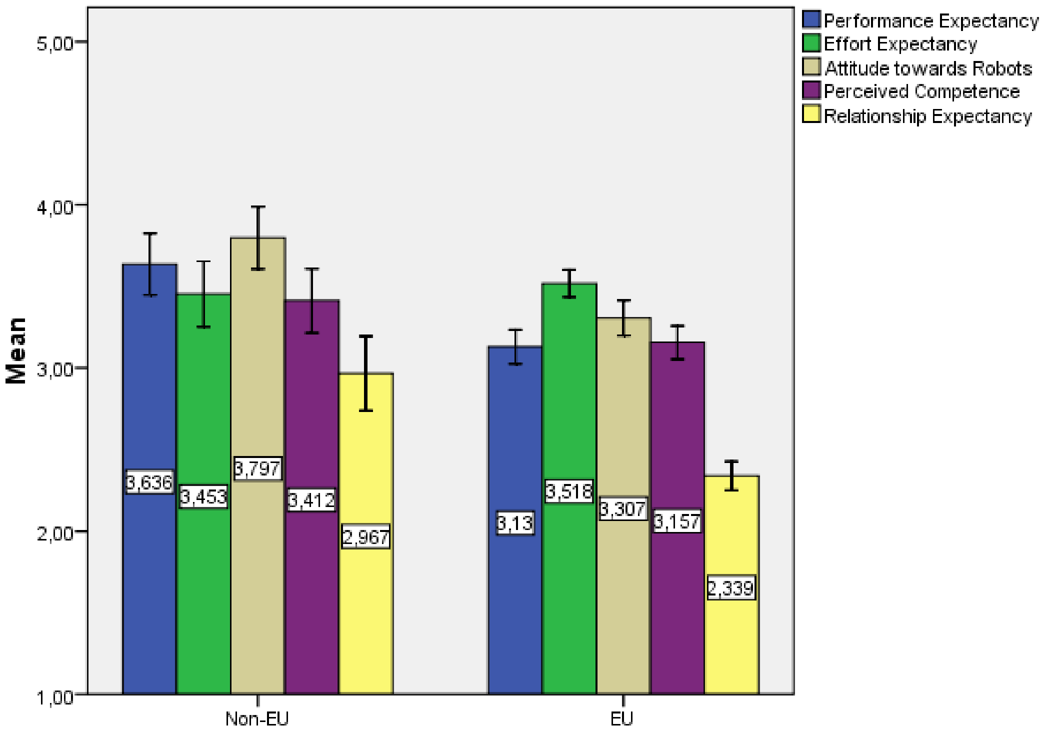

Figure 4: Social acceptance – non-EU and EU citizens

3.3.4.2.4 Gender Differences

User experience (see Figure 5) differs high significantly ($p<0.01$) in gender in terms of feeling of security, as female participants show a higher feeling of security than male participants ($p=0.002$). However, female and male participants did not experience the robots HOAP-3 and HRP-2 significantly different in terms of embodiment, human-oriented perception and Emotion.

Furthermore, there are great differences in the acceptance of robots between male and female participants (see Figure 6). Male participants show significantly higher ($p<0.01$) Relationship Expectancy than female participants ($p=0.0$), as well as Perceived Competence ($p=0.0$), attitude towards robots ($p=0.0$), performance expectancy ($p=0.0$), and significantly ($p<0.05$) more positive effort expectancy ($p=0.012$).

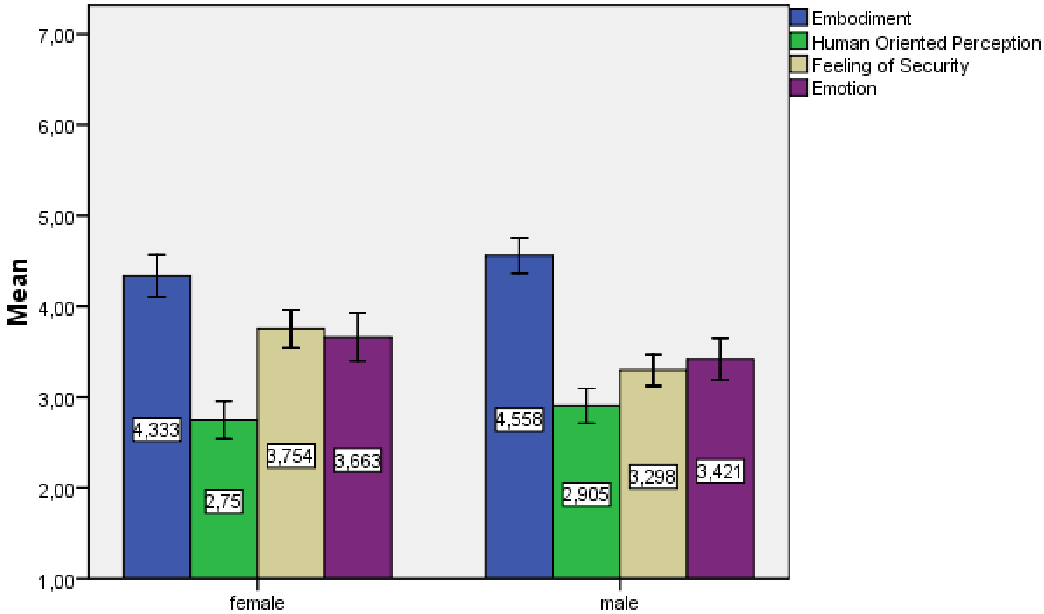

Figure 5: User experience – average ratings of females and males

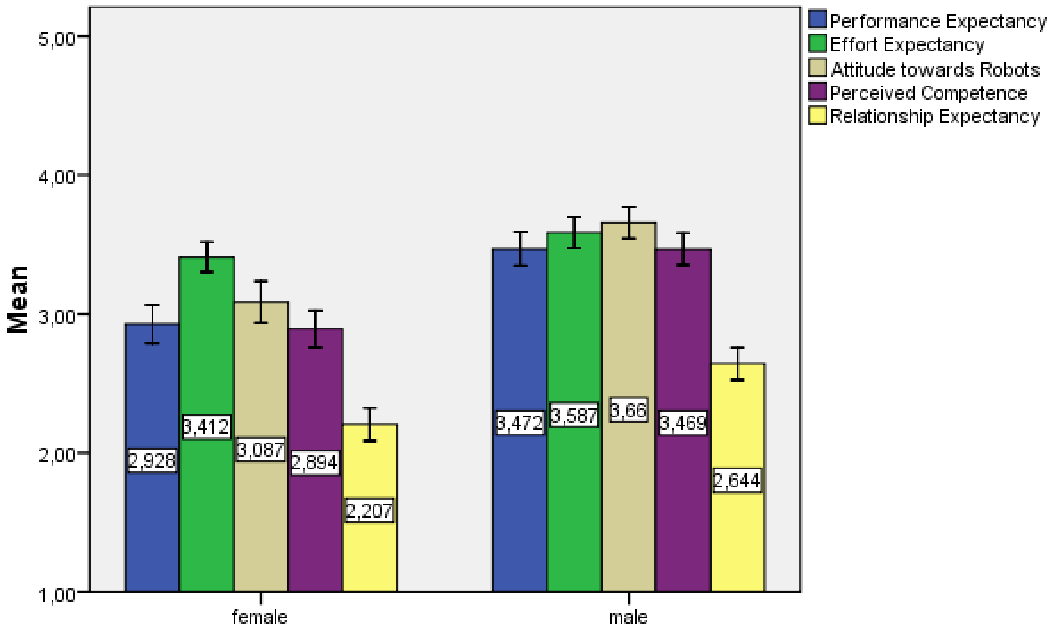

Figure 6: Social acceptance – average ratings of females and males

3.3.4.2.5 Differences between HOAP-3 and HRP-2

The HOAP-3 robot was experienced significantly more positive ($p<0.0$) regarding embodiment ($p=0.0$) and human-oriented perception ($p=0.0$). The indicator emotion is also rated significantly higher ($p<0.05$) for HOAP-3 ($p=0.049$).
However, the HRP-2 robot scores in terms of Feeling of Security ($p=0.012$), which is perceived as significantly higher than the Feeling of Security of HOAP-3 ($p<0.05$).

Concerning differences in acceptance of the two robots, it could be shown that the effort expectancy of HOAP-3 is significantly higher (p<0.01) than the effort expectancy of HRP-2 (p=0.003). This means that the effort to work with HOAP-3 is expected not that high than the effort to work together with HRP-2. The SoAc indicators performance expectancy, attitude toward robots, competence and relationship expectancy do not differ significantly between HOAP-3 and HRP-2.

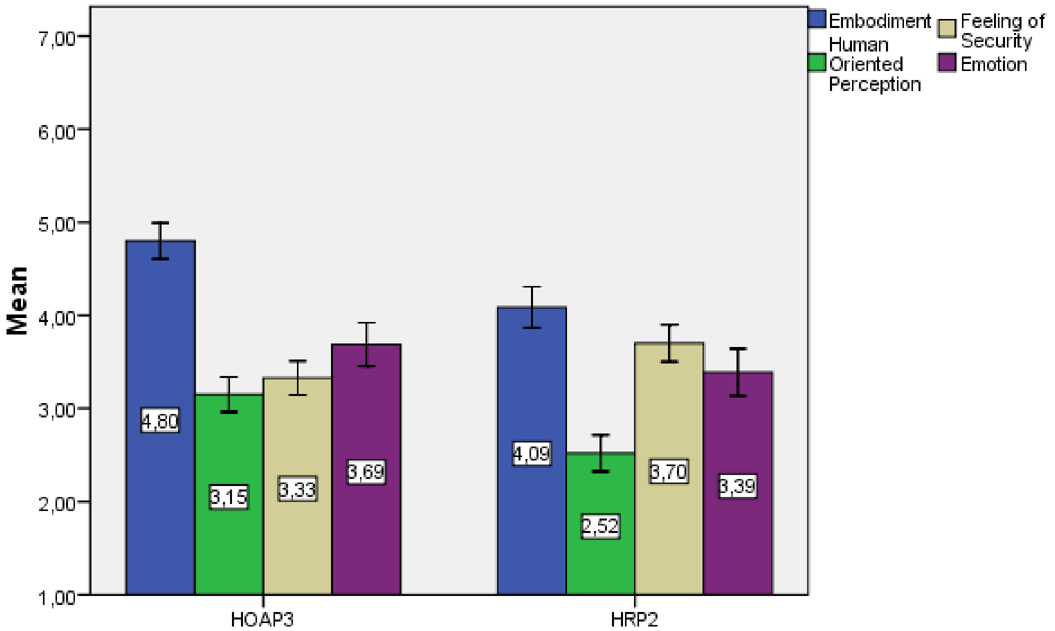

Figure 7: User experience – average ratings for HOAP-3 and HRP-2

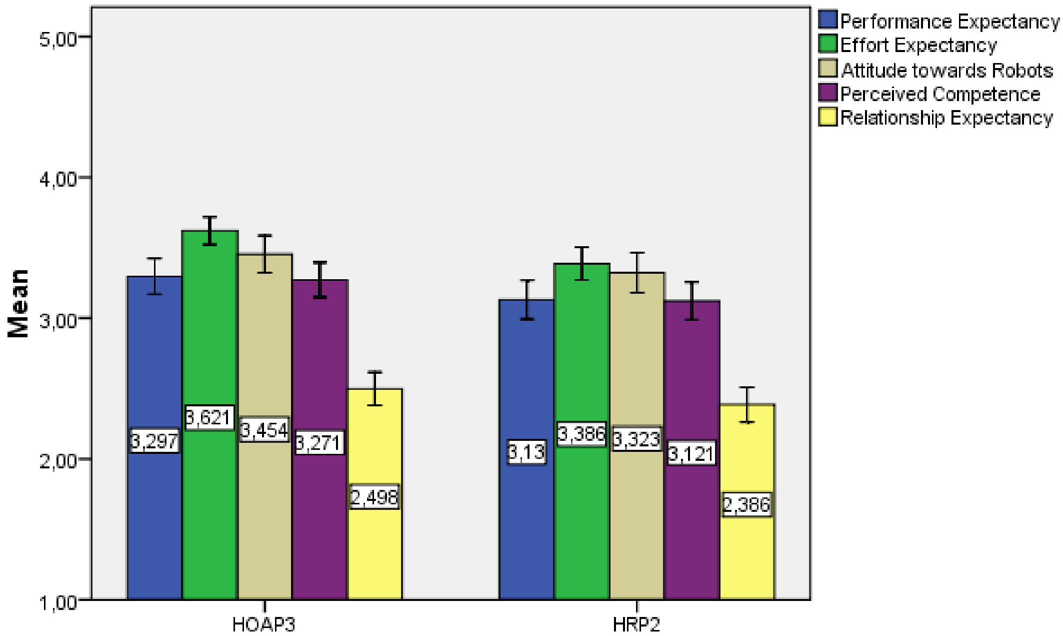

Figure 8: Social acceptance – average ratings for HOAP-3 and HRP-2

3.3.4.2.6 Differences in Age

No significant correlation could be examined between the user experience and user acceptance of robots and the age of the participants. Only Attitude towards robotics shows a slightly significant difference within age. The older the participant, the more positive is the attitude towards robots (p=0.035, Spearman´s rho: 0.106).

3.3.4.2.7 Differences "Worked in HRI" and "Not Worked in HRI"

Concerning UX, the indicators embodiment (p=0.020) and human-oriented perception (p=0.006) are perceived significantly better by participants who have already worked in HRI, while Feeling of Security is significantly rated higher by participants who have not worked in HRI yet (p=0.037) (see Figure 9).

Interestingly, participants who have already worked in HRI, show (significantly) higher acceptance in terms of all acceptance indicators defined. Performance expectancy, attitude towards robots, perceived competence and relationship expectancy differ high significantly for the two groups (p=0.00), and effort expectancy differs significantly on the 5% level (p=0.02) (see Figure 10).

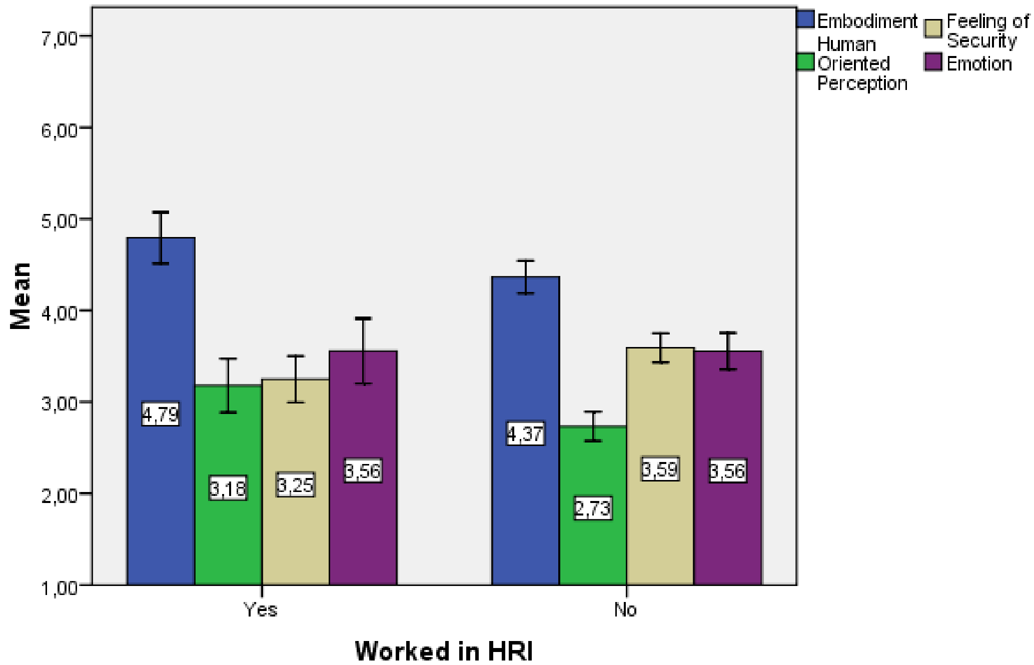

Figure 9: Average ratings of user experience of participants who worked in HRI versus participants who did not work in HRI

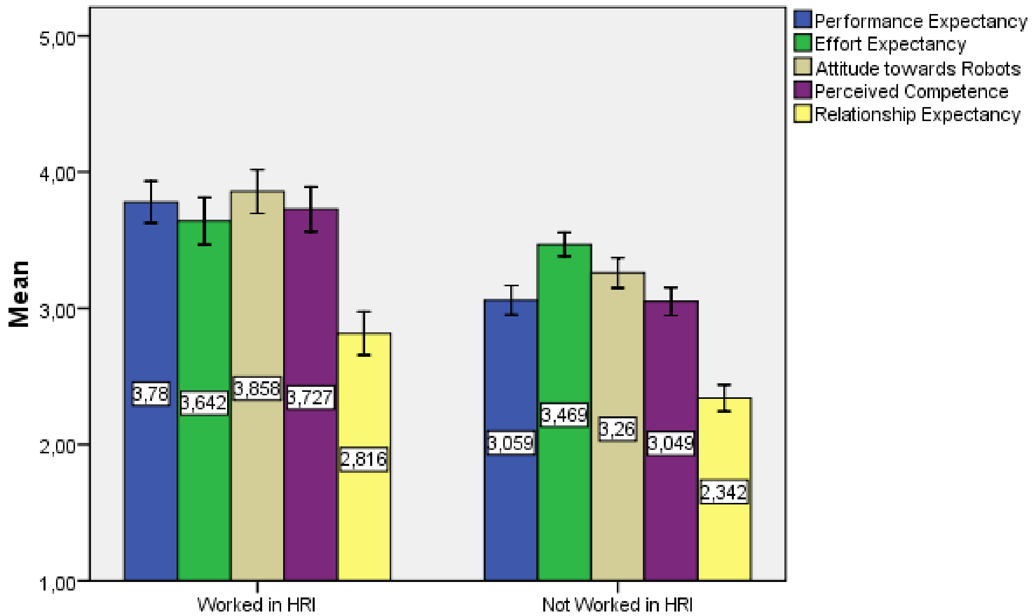

Figure 10: Average ratings of social acceptance of participants who worked in HRI versus participants who did not work in HRI

3.3.4.2.8 Differences concerning Participation in HRI Experiment

A Mann-Whitney test revealed high significant differences within UX and SoAc of participants who have participated in an HRI experiment before and those who have not. The robots' embodiment($p=0.010$) as well human-oriented perception ($p=0.00$) are rated significantly better by participants who have participated in an HRI experiment yet, whereas feeling of security is experienced significantly better by not HRI experiment experienced participants ($p=0.008$). Emotion does not show significant differences.
Interestingly, HRI experiment experienced participants show significantly higher acceptance of robots at all acceptance concerns ($p<0.01$). They expect higher performance, less effort, more competence as well as better relationship when working with robots and show a higher positive attitude towards robots than the participants who have not participated in an HRI experiment yet.

3.4. Second Iteration of Remote Control Design by Means of Expert Evaluation

3.4.1 Study Setting

In order to identify usability problems of an iterated version of HP's remote control interface, an expert evaluation was conducted. This expert evaluation included a cognitive walkthrough as well as a heuristic evaluation of the current interface. The results of the expert evaluations should then be used as the basis for another iteration of the interface prototype (see D3.8@M36).
Originally, a cognitive walkthrough with six experts in HCI and/or design was planned. As it turned out that a cognitive walkthrough was limited to learnability issues, we decided to conduct a heuristic evaluation in order to have a broader view on different usability issues. Thus, we switched to the conduction of a heuristic evaluation after three walkthroughs. The results presented below involve insights gained from both methods (cognitive walkthrough and heuristic evaluation). The expert evaluations were conducted between June and July 2009 at the University of Salzburg and involved six experts altogether (3 females, 3 males). The participants were all experts in HCI, with a background in communication science, computer science, psychology, or interaction design. Half of the experts took part in the cognitive walkthrough, and the other half conducted a heuristic evaluation of the HR interface. More details on the iterative interface design in general can be found in D3.8@M36.

3.4.2 Instruments

The tasks for the cognitive walkthrough were the following:

1) Move the robot to the table
2) Lift the cube
3) Carry the cube back to the starting point
4) Put the cube down to earth

With each task, the experts were presented an ideal, step-by-step solution for the task. After completing a step of the task, the experts were asked about the user's intentions and possible problems.
The tasks of the heuristic evaluation (conducted according to Nielsen, 1994) comprised the following tasks, including one example task:

1) Example task: Move the robot to the table
2) Lift the cube

3) Move the robot backwards
4) Put the cube down to earth

As in the cognitive walkthrough, each task was split up into single steps for solving the task accurately. During the evaluation, the experts had to indicate which of the given heuristics were violated and rate them according to their severity. Furthermore, the experts should point out possible problems not covered by the heuristics as well as suggestions for improvements.

3.4.3 Procedure

At the beginning of the cognitive walkthrough/heuristic evaluation, the experts got a short introduction, pointing out the procedure and the aim of the evaluation. During the cognitive walkthrough, the experts should indicate how a user would typically use the interface and which problems the user could have. After walking through all tasks, the evaluators should give general comments and recommendations concerning the interface design.
During the heuristic evaluation, the experts should indicate which of the presented heuristics were violated by the interface and how these problems of the interface could be solved.

3.4.4 Overview of Results

Taken the problems of the cognitive walkthrough and the heuristic evaluation together, 41 usability problems of the remote control interface could be identified. Thereof, 35 problems were different (6 problems were indicated in both evaluation methods). In the cognitive walkthrough, 19 usability problems were found. In the heuristic evaluation, 22 problems were identified. Below, a summary of the problems found (grouped according to the problem area addressed) is given. A detailed report on the results can be found in D3.8@M36.

User language: The labelling of the interface elements should be easily comprehensible. Some parts of the interface are misleading, for instance, “connect to socket” means connect the HR interface with the robot, which is unclear. Furthermore, the description of the strategies possible was difficult to understand.

Distance to objects: One of the main problems during the evaluation was that it is not possible to estimate the distance to other objects. When navigating the robot in the virtual reality it is difficult to estimate the size of the steps of the robot.

Cognitive load: A problem of the navigation control part of the HR interface is that the navigation is static and robot centred (through its vision), which could lead to user errors while controlling the robot. Another problem encountered by the expert evaluators is that the user has to know and to remember a specific ID of an object in order to perform an action. Due to the lack of feedback the user has to know in which arm the robot carries a thing.

Control: The user should always have the control of the robot. Therefore a button should be available which can stop the current action of the robot, if the STOP button only stops the robot.

Efficiency: For the efficiency of controlling a robot it is important that the robot supports moving backwards or making side steps. In the HR interface it is not possible to make a step back instead the robot turns 180 degrees and moves a step. Not implemented but also included in the evaluation was the head moving feature. This feature should enable a “home” button in order to move the head back to its original position (horizontally and vertically)

Feedback: A major drawback of the HR interface is the missing feedback when grabbing or dropping an object. Furthermore the user is not aware if the robot carries an object or if an action performing by the robot has been finished.

Error prevention: The navigation of the robot is enabled when the user selects a specific action, for instance “grab the object with the right hand”. Moreover other actions are enabled as well, like “go to object”.

Transparency: Typing in a number of an object in order to perform a task is not very intuitive. The window appearing then rather recalls on a calculator. As a consequence, the next step for the user will not be obvious.

3.4.5 Changes/improvements of Interface v02 compared to Interface v01

This subsection describes what has changed during the first evaluation and the second evaluation, based on the results of the evaluations. A detail description of problems identified in the second expert evaluation is explained in D3.8@M36.

The most critical usability problem, (moving the robot and speed up) of the first version of the interface could be eliminated. The current version offers the control of the speed and the change of the direction at the same time. Through the new interaction paradigm for controlling the robot, new usability problems have been appeared. Furthermore, the highest rated problem of the first expert evaluation, the missing connection between speed buttons and slider, has also been eliminated.

Another critical usability problem identified in the first HR interface version was that the interface was too unstructured and the grouping of the GUI elements could still be improved. For instance now the “Stop” has been placed in the middle of the navigation of the robot and therefore is easily accessible.

A problem just mentioned in the second iteration was the view of the robot camera which is still small and therefore it is difficult to navigate the robot efficiently without a map.

Because of the information overhead, the message log display could still be improved by reducing the amount of information.

4. Evaluation Studies WP4

This section describes all evaluation studies conducted within WP4. These studies include a mixed reality simulation of human-robot collaboration, a user study on the HRP-2 final demonstrator and a group-based cognitive walkthrough.

4.1. Mixed Reality Simulation of Human-Robot Collaboration

4.1.1 Study Setting

In order to pretest the evaluation concept for the final HRP-2 demonstrator, a mixed reality simulation of a similar scenario was developed. A user study with 24 test subjects, counter balanced in age and gender, was conducted by PLUS in August 2008 at the University of Applied Sciences Salzburg, Austria.
This evaluation study was conducted as Wizard-of-Oz (WOz) user-study in a mixed reality environment with a 3D model of the HRP-2 robot acting in the virtual environment. The simulation was implemented with the Crysis game engine 73 (more details on the technical implementation can be found in Weiss et al., 2009d).
An object (board) from the real world, which was enhanced into the virtual world, built the interaction point the collaboration task between the human and robot was based. The task was to carry and mount a board together with the robot. In order to answer the content related research question "How do differently simulated feedback modalities influence the human-robot collaboration" we tested four different experimental conditions. The conditions of the experiment were the following:

- Condition 0: Interaction without feedback
- Condition 1: Interaction with visual feedback (a blinking light on the head showed that the robot understood the command)
- Condition 2: Interaction with haptic feedback (an electric engine simulated the lifting support of the robot)
- Condition 3: Interaction with visual and haptic feedback in combination

Moreover, it was of interest to get an understanding of the methodological challenges for the final integrated demonstration of the human-robot collaboration with the HRP-2 robot (see section 5.2). This study was conducted as a preliminary user study for the final demonstrator scenario evaluation and was based on the WOz approach. Through the WOz method a mixed reality simulation of a construction site scenario could be enabled, with the HRP-2 robot as 3D model. Therefore, the Crysis game engine was used in order to implement the prototype of the scenario. Within the prototype of the scenario we combined the 3D model of the HRP-2 with the simulation and furthermore direct manipulation (including force feedback) of the HRP-2 could be enabled.

In the user study the following research questions were addressed:

- How do novice users experience the collaboration with the humanoid robot HRP-2 in a mixed reality scenario?
- How do users perceive the interaction in terms of usability taking into account different feedback modalities?

- Does the general attitude towards robotics change because of the interaction with the mixed reality simulation?
- How do people imagine a future society with humanoid robots as co-workers, after interacting with the mixed reality simulation?
- What do people think about the acceptance of humanoid robots after interacting with the mixed reality simulation?

With the collaboration of the simulated robot, one task the user study was based on had to be conducted with the mobile board as “input modality”. Figure 11 shows the setting of the mixed reality scenario. The task which had to be conducted together with the robot is introduced in the following scenario:
“Imagine you are working at construction area and get the task from your principal constructor to mount a gypsum plaster board together with a humanoid robot. You can control the robot with predefined voice commands, to carry out the following action sequences”.

Task description: Lift move and mount a gypsum plaster board together with a humanoid robot. This task consists of the following action sequences:

- Start the interaction by calling the robot
- Lift the board together with the robot.
- Move the board together with the robot to the right spot.
- Tilt the board forward to the column together with the robot.
- Tell the robot to screw the board.

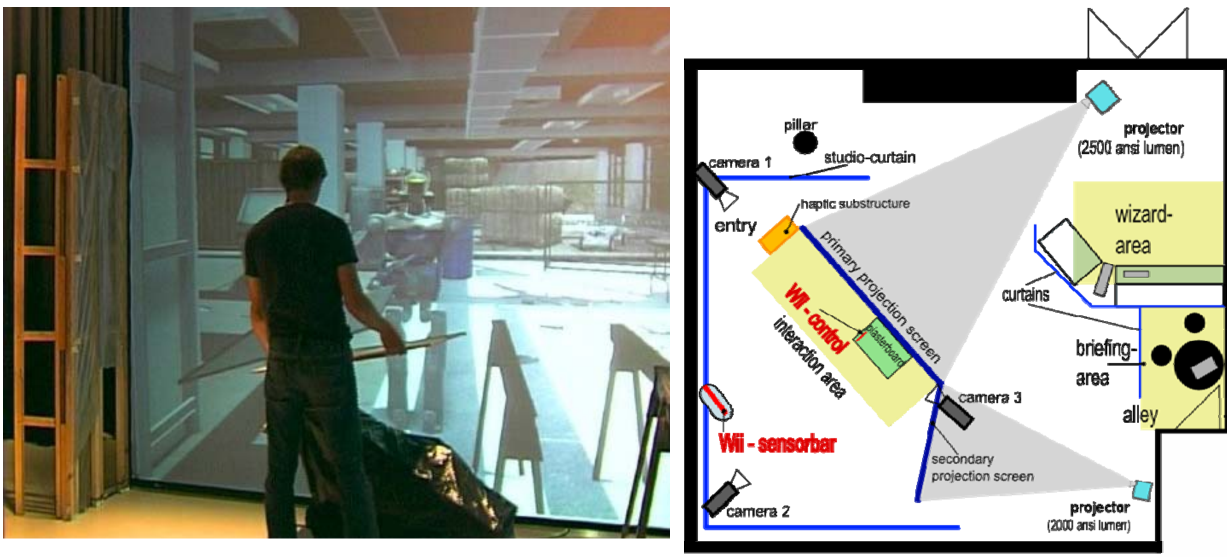

Figure 11: Study setting mixed reality simulation with HRP-2

4.1.2 Instruments

The instruments of the evaluation were exactly the same as already used in the laboratory studies with HOAP-3. For further details see D3.4-7@M30.

4.1.3 Procedure

First the user study started with a basic questionnaire followed by the NARS questionnaire. The test subjects had to fill them in before they saw the setting and the robot. After that the scenario and the task were introduced to the test subjects in order avoid misunderstanding. When the participants had finished the task the experimenter conducted an interview regarding their thoughts and feelings during the interaction with the robot, on suggestions for how to improve future interaction in order to make it easier. Additionally, the participants were asked to rate the task on a scale from very easy (1) to very difficult (5) on a five point Likert scale. Afterwards the participants had to fill in the standardized questionnaire in the following order: (1) PANAS, (2) SUS, (3) AttrakDiff, (4) UX questionnaire, (5) SoAc questionnaire, (6) Basic Questionnaire (second round), and (7) NARS (second round). At the end of the study, the participants were interviewed about societal impact issues.

4.1.4 Overview on Results

4.1.4.1 Usability

To measure the usability of this user study we especially were interested on the four different feedback conditions. For the simulation in common, a score of 74.90 was revealed by the SUS. Concerning the different feedback conditions the SUS disclosed the following values: Con0:66.25; Con1: 71.25; Con2: 83.93, Con3: 79.17. The usability of the system was rated best by the participants in the second condition, which means, the perception of haptic feedback was most usable and that a combination with visual feedback (blinking light) could not show any improvements in terms of usability. Nevertheless, there were no significant statistical differences ($F(3, 20) = 2.30$, $p<0.05$).

Effectiveness: 11 out of 24 test subjects were able to conduct the given task successfully according to the ideal way of solution. A successful completion but with errors in the separate action sequences was carried out by 10 participants, whereas 2 out of the 10 needed help in order to solve the task. One participant voluntarily aborted the interaction after several failed trials. Through the task completion rate, the mixed reality simulation showed in general a good effectiveness. The difficulty of the task was perceived differently regarding the four feedback modalities.

Efficiency: The task was solved with a mean task duration of 02:14 minutes (SD: 62.86 sec; range: 01:05-05:20). As the ideal task duration time was set-up with 2 minutes for the task an average efficiency is indicated. An overview on the results can also be found in the following Table 8:

	Task completion				
TP	**ideal way**	**with help**	**wrong approach**	**Task duration**	**number of errors**
TP1			aborted		
TP2	X			00:01:33	0
TP3			X	00:02:34	2
TP4	X			00:02:27	0
TP5	X			00:02:58	0
TP7	X			00:02:00	0
TP8			X	00:01:05	3
TP9	X			00:02:15	0
TP10			X	00:01:40	1

TP11			X	00:02:15	4
TP12			X	00:01:30	1
TP13	X			00:01:05	0
TP14			X	00:02:00	3
TP15			X	00:02:00	2
TP16	X			00:01:26	0
TP18			X	00:01:40	4
TP19			X	00:03:00	1
TP20	X			00:01:20	0
TP21			X	00:03:00	2
TP22	X			00:01:15	0
TP23	X			00:01:50	0
TP24		X		00:05:20	6
TP25		X		00:04:36	9
TP26	X			00:02:25	0

Table 8: Overview of the subtjects' task completion, their duration and number of errors within the task.

4.1.4.2 User Experience

In order to get results about the general user experience of mixed reality simulation, the AttrakDiff questionnaire was used. Results of this questionnaire showed that the construction site scenario was positively perceived by the participants. The mean values of the PQ (mean: 0.85, SD: 0.92), HQI (mean: 0.60, SD: 0.88), HQS (mean: 1.13, SD: 1.09), and ATT scale (mean: 0.71,SD: 0.99) were all close to 1 (scale -3: negative word pole to +3: positive word pole). The best value was shown by the hedonic quality stimulation which means that the participants were encouraged to interact with the mixed reality environment. Furthermore, statistically significant differences were revealed for the HQ-S scale ($F(3.20) = 3.20$, $p<.05$) and for the ATT scale ($F(3.20) =3.43$, $p<.01$). Through a post-hoc test (LSD) it was shown that condition 3 (the combination of visual and haptic feedback) was experienced significantly better in the hedonic quality of simulation than all the other conditions. Condition 3 was significantly better rated in terms of attractiveness than condition 0 (interaction without any feedback) and condition 1 (interaction with visual feedback). More detailed insights on user experience of mixed reality simulation were obtained by the UX questionnaire (scale 1: absolutely disagree to 7: absolutely agree), covering the following indicators: emotion (mean: 5.03, SD: 0.62), embodiment (mean: 4.29, SD: 0.91), feeling of security (mean: 4.72, SD: 0.93), human-oriented perception (mean: 3.77, SD: 1.16), and co-experience (mean: 3.08, SD: 1.43). The results show that there is a positive experience of the mixed reality simulation in general, especially in terms of emotions and feeling of security.

The indicator embodiment ($F (3.19) = 3.35$, $p<.05$) revealed significant differences. Through a post-hoc test (LSD) it could be shown that Con0 (interaction without feedback) was perceived significantly better in terms of embodiment than in Con1 (interaction with visual feedback). Thus it can be concluded that the blinking yellow light on the robot's body negatively influenced its general embodiment.

The PANAS questionnaire indicated that after the interaction with the mixed-reality scenario all participants except of three male (TP04 = 33, TP11 = 33, TP16 = 33) and four female participants (TP15 = 37, TP19 = 31, TP21 = 33, TP23 = 36) had a lower positive affect than normative average (male: 32.06, female: 30.06). Asking the participants directly, no one of them stated a worse negative affect after the interaction. Thus it can be concluded that the mixed-reality scenario did not influence participants' affective state.

4.1.4.3 Social Acceptance - SoAc Questionnaire

In order to get more insights on social acceptance, the SoAc questionnaire (scale 1: absolutely disagree to 5: absolutely agree) had to be filled in by the participants. This questionnaire comprised the following indicators: performance expectancy (mean: 3.55, SD:0.85), effort expectancy (mean: 3.75, SD: 0.64), attitude towards using technology (mean: 3.70, SD: 0.83), self efficacy (mean: 3.60, SD: 0.78),attachment (mean: 2.21, SD: 0.92), forms of grouping (mean: 3.10,SD: 0.91), and feeling of reciprocity (mean:2.92, SD: 0.98).

The results of the questionnaire show that a mixed-reality set-up is feasible to investigate general questions on the social acceptance of human-robot interaction. An ANOVA analysis showed that the four different experimental conditions influenced the results of three indicators: performance expectancy ($F (3.20) = 5.84$, $p<0.05$), forms of grouping ($F(3.20)$ 6.26,$p<0.05$), and attitude towards technology ($F(3.20) = 6.10$, $p<0.05$). A post-hoc test (LSD) revealed that performance expectancy was rated significantly lower in Con1 (interaction with visible feedback) than in all other conditions. The same effect could be observed for the indicators forms of grouping and attitude towards technology, which were also rated significantly lower in Con1compared to all other conditions.
According to the NARS questionnaire, there were no significant changes due to the interaction with the mixed-reality scenario in any of the three attitude scales.

4.1.4.4 Societal Impact Interview

When asking about robots' impact on the quality of life, both positive and negative aspects were mentioned. Less physical harms, more security on the working place as well as higher efficiency and productivity resulting from fewer mistakes at work were often mentioned as positive effects. Negative effects pointed out were higher unemployment as well as impacts on the quality of companionship at work, as robots are supposed to lack of communication skills and personality.

When asking participants how robots will be integrated into future working life, they mainly answered that robots are appropriate for monotonous work, like for example assembly line work, dangerous and hard physical work as well as dirty work. Thus, the answers were mostly in accordance with the classical 3D´s “dirty”, “dangerous” and “dull”. Moreover, robots were proposed for medical work like surgery because of their specific precision skills as well are for taking care of the elderly (e.g. for entertainment in retirement home) or for supporting handicapped people. Participants often assumed that more anthropomorphized the robots would lead to higher trust and easier collaboration. Interestingly, one participant could not imagine any ways to integrate robots into future working life after interacting with the simulated HRP-2-robot.

Concerning the influence of the usage of robots on the education system, the participants showed different views on this aspect. Some participants stressed the high learnability skills of children, saying that they will learn to handle robots easily when they grow up with them. Other participants pointed out a strong need for technology knowledge. They therefore recommended to enhance technological education at school as well as on work and university level. In general, a higher educational level of humans was expected as an advantage of the increased employment of robots, resulting in more time for education.

Robots in a future society are imagined differently by participants. Some especially stress the great influence of mass media on the imagination of future robots. Overall, science and politics are supposed to have the greatest influence on the future integration of robots. Most of the participants agree that robots will be supported if their employment leads to higher productivity.

4.2. User Study on the HRP-2 Final Demonstrator

The goal of this evaluation study was the assessment of the HRP-2 final demonstrator of the ROBOT@CWE project in terms of usability, social acceptance, user experience and societal impact. Furthermore, the user study should help to identify problems arising during the interaction with the robot and to offer recommendations how to improve the scenario. The central research questions for this evaluation study are:

- How is the HRP-2 robot perceived in terms of usability, user experience, social acceptance and societal impact?
- Is there a difference in terms of perception of usability, user experience, and social acceptance if the participants have (1) Asian nationality, (2) Western nationality?
- How does the expert tele-operator (OG) experience the interaction in terms of presences and performance?
- How does the participant experience the relationship towards (1) the autonomous HRP-2 robot, (2) the tele-operated HRP-2 robot?

Next to getting insights into cultural differences between Western and Asian participants as well as into the experiences of the tele-operator, the final demonstrator study should also demonstrate that the application of a broad method mix allows addressing all factors in one user study.

The overall story of the final demonstrator scenario is that a manager of a company asks a trio (human-robot-human) to move an object from one place to another in a construction site.

The following roles are involved in the scenario:

- The manager who initiates the interaction scenario via the BSCW system
- The human operator located in Germany (OG) with a haptic system developed by TUM partner.
- The human operator located (OJ) in Japan located in the construction site located in Japan and represented by a novice user.
- The robot humanoid HRP-2 that is present in the construction site and will physically interact with the collocated human operator in Japan (OJ).

4.2.1 Study Setting

The final demonstrator user study with the HRP-2 robot was carried out in October 2009 (8^{th} – 14^{th} of October) at Tsukuba University in Japan (CNRS/AIST) and at the Technical University at Munich (TUM) in Germany. Overall, 12 participants (6 male, 6 female) took part in the study. Half of the participants had Asian, half of them had Western cultural background. The average age of participants was 30 years, with the youngest participant aged

22 and the oldest aged 40. Most of the participants have a university degree (9 out of 12). Those who do not have a university degree have finished vocational school (1 out of 12), middle school (1 out of 12) or secondary school (1 out of 12). Four of the participants have a job, five are visiting school or university, and two are seeking work.
None of the participants owns a household robot. One of the participants has automatic regulation of light intensity, one has automatic regulation of access, five use automatic regulation of room temperature and 6 use automatic regulation of household devices.

For the final demonstrator study, the following pre-conditions were defined (see Table 9): equal distribution of men and women as well as of Western and Asian participants, two age groups (group 1: 18-29 years; group 2: 30 years and older), no pre-experience with robots, good language skills in English (necessary for the test procedure) and very good language skills in one of the following languages: English, Japanese, French, Spanish or German (necessary for filling in the questionnaires).

	female	male
	Asian/Western	Asian/Western
18 - 29 years	1/2	1/2
30 years and older	2/1	2/1

Table 9: Pre-defined profile of participants

4.2.2 Instruments

In the final demonstrator study, participants (acting as the human operator in Japan, OJ) had to lift, carry and put down a table collaboratively with the HRP-2 robot. During lifting and putting down the table, HRP-2 was tele-operated, and during carrying the table, HRP-2 was walking autonomously. Therefore, the HRP-2 robot was tele-operated by the human operator in Germany (OG). The accomplishment of this task was video-taped and accompanied by a retrospective think aloud. In order to get additional physiological data during interaction, heart rate variability (HRV) was measured of both the participant interacting with the robot (OJ) and the operator controlling the robot (OG).
Additionally, the following6 questionnaires had to be filled in by the participants: PANAS, SUS, AttrakDiff, UX questionnaire, SoAc questionnaire, NARS questionnaire. Furthermore, every participant was interviewed on societal impact. Therefore, four open questions concerning the societal impact of robots were discussed.
The operator (OG) had to complete an online questionnaire (see Annex) on how he experienced the interaction with the Human-System Interface (haptic interface) in Munich after each task completion. The questions were adapted from (Basdogan et al. 2000, Ho et al. 1998) and had to be rated on a 7 point Likert scale.

4.2.3 Procedure

The final demonstrator user study was conducted in the following manner: First, the test leader welcomed the participant. The participant then received the Suunto HRV belt and was asked to put it on. At the same time, the tele-operator in Munich (OG) also put on the HRV belt. Next, the goals of the study as well as the test procedure were explained. After signing the video permission, collecting demographic data of the participant and filling in the NARS questionnaire on the participant's general attitude towards robots, the participant was brought to the robot. Before the interaction started, the scenario and the instruction were described by the test leader (see below).

Scenario: Imagine you are working at a construction site and you receive a task from your principal constructor: carrying an object from one place to another together with a humanoid robot which is partly acting autonomously and partly operated by a human expert operator. The principal instructor tells you the task via a computer interface:
Instruction: The task is to carry a table from Place A to Place B together with the humanoid robot HRP-2. This task is split into 4 action sequences:
Action Sequences: **Action Sequence 0:** The robot is sent to the table by the principal instructor **Action Sequence 1:** Lift the table together with HRP-2 **Action Sequence 2:** Walk together with HRP-2 from Place a to Place B **Action Sequence 3:** Put down the table together with HRP-2

The interaction between the human and the robot takes places in sequences 1-3 (see Figure 12). Sequence 0 does not require any interaction between the human and the robot.
After the task conduction (all four sequences completed), both the participant (OJ) and the tele-operator (OG) put off the HRV belt. After that, the tele-operator in Munich (OG) fills in the online questionnaire on how he experienced the interaction. The participants in Japan are asked to fill in the questionnaires handed out (PANAS, SUS, AttrakDiff, UX questionnaire, SoAc questionnaire, NARS questionnaire). Finally, the participants are interviewed regarding societal impact of robots in future societies.

Figure 12: Lifting the table and walking together with HRP-2 (action sequences 1 and 2)

4.2.4 <u>Overview on Results</u>

4.2.4.1 Usability Measures

To assess the effectiveness and efficiency of the interaction in the HRP-2 final demonstrator scenario the general task completion was measured and the number of attempts and their duration in seconds was recorded for the action sequences 1 to 3 (as in action sequence 0 no interaction between the user and the robot happened). Action sequence 1 was furthermore split into sequence 1: human operator grasp table and sequence 1.1 human operator and user lift table. Tabel 10 gives an overview of the results.

		Sequence 1		Sequence 1.1		Sequence 2		Sequence 3	
	Task completion	count	dur	count	dur	count	dur	count	dur
TP1	yes	3	175/186/181	3	12/24/23	2	18/252	1	26
TP2	yes	3	180/269/198	3	24/23/24	3	28/11/168	1	50
TP3	yes	5	348/229/194/66/190	4	26/26/25/25	4	10/81/56/141/51	1	113
TP4	yes	1	229	1	25	1	105	1	55
TP5	yes	2	246/190	2	27/23	2	10/105	1	63
TP6	yes	1	175	1	26	1	155	1	65
TP7	no	5	55/224/197/185/17	3	26/24/24	3	102/83/77		
TP8	yes	2	274/177	2	24/24	2	10/200	1	61
TP9	yes	2	197/204	2	26/27	2	16/293	1	52
TP10	yes	2	193/186	2	13/23	1	295	1	71
TP11	yes	1	196	1	22	1	142	1	55
TP12	yes	1	194	1	25	1	121	1	64

Table 10: Task completion and number of attempts/duration of the different action sequences

Retrospective Think Aloud: When analyzing the retrospective thinkaloud data, 14 positive and 25 negative statements concerning the scenario were found. Furthermore, 9 suggestions for improvement of the scenario were given. Detailed results of the retrospective think aloud data can be found in Deliverable D2.10@M36.

Perceived Dominance:
During the retrospective think aloud we asked the participants how they experienced their relationship towards the robot and the human operator in terms of dominance. We wanted to know how they perceived the dominance in the three action sequences: Action Sequence 1: Lifting the board, action sequence 2: Walking with HRP-2, action sequence 3: Putting down the board. Four different answer categories could be derived from the open ended answers of the participants to describe the leading role during the action sequences: human operator, user (meaning the participant himself/herself), the autonomous robot, and team (chosen only by one participant, who explained that there was no leading but only team work during the interaction). The answer category autonomous robot was chosen, when a participant explained after the experimenter probed if they mean the human operator or the robot, that they mean that the robot made the final decisions or actions and explicitly not he human operator. The results regarding dominance can be found in Table 11 and indicate that in most cases participants experienced the change in the leading role.

TP	Action Sequence 1	Action Sequence 2	Action Sequence 3
TP1	human operator	user	human operator
TP2	human operator	user	human operator
TP3	user	user	user
TP4	team	team	team
TP5	user	user	user
TP6	human operator	user	human operator
TP7	autonomous robot	autonomous robot	autonomous robot
TP8	autonomous robot	autonomous robot	autonomous robot
TP9	autonomous robot	autonomous robot	autonomous robot

TP10	human operator	user	human operator
TP11	human operator	user	human operator
TP12	autonomous robot	user	autonomous robot

Table 11: Perceived Dominance

SUS: This questionnaire should give insights on how the participants perceived the usability of the autonomous HRP-2 robot when collaboratively solving the task. The SUS questionnaire revealed a cumulative score of 47.08 for HRP-2. In general, this result indicates that users do not like the autonomous HRP-2 robot in terms of usability. In other words, participants perceived the interaction capabilities of the autonomous HRP-2 as improvable for solving the specific interaction scenario.

Difficulty ranking: After conducting the task together with the HRP-2 robot, participants had to estimate the difficulty of the task conduction (scale ranging from 1: very easy to 5: very difficult). Table 12 gives an overview of the average rating of the different task sequences, showing that the all task sequences were rated as easy or rather easy, except of walking together with the robot, which was rated as neither very easy nor very difficult.
Furthermore, they should rate the contribution of the different actors to the task performance (scale ranging from 1: not good at all to 7: excellent). Table 13 gives an overview of the participants' rating and the operator's rating. The participants rated the contribution of the single actors as good or rather good, except of the contribution of the robot, which was rated neither very positive nor very negative.

	Overall difficulty of task	**Lifting table together**	**Putting table down together**	**Walking together**
Mean	2.50	1.42	1.58	3.50
SD	0.29	0.19	0.29	0.32

Table 12: Average rating of difficulty of task sequences

	User (OJ)	**Robot**	**Operator (OG)**	**User & Operator**	**User & Robot**
User rating (OJ)	mean: 5.38 SD: 0.22	mean: 4.83 SD: 0.46	mean: 5.67 SD: 0.31	mean: 6.00 SD: 0.21	mean: 5.75 SD: 0.28
Operator rating (OG)	mean: 6.50 SD: 0.22	X	mean: 6.40 SD: 0.22	mean: 6.40 SD: 0.27	X

Table 13: Average contribution to performance (rated by user and operator)

Significant differences concerning gender could be found for the rating of the difficulty when walking together with the robot from Place A to Place B, as the ratings of females were significantly higher compared to males (p=.029). This means that males experienced walking together with HRP-2 as more difficult than females.
Significant differences could also be found for the overall rating of the task difficulty, as Western participants gave significantly higher ratings compared to Asian participants (p=.012). This means that Western participants experienced the task as more difficult than Asians.

Heart Rate Variability:
To gain more objective insights on the "emotional state" of the user during the interaction (not only insights on the affective state after the interaction by means of self reporting measures, see section 4.2.4.3 User Experience Measures) the heart rate of the user and the human operator was measured. Based on this data we calculated an arousal feature based on heart rate variability (HRV) as a continuous metric (sympatho-vagal balance ratio) and synchronized it with the video data (see Figure 13). The following Table 14 gives an overview about the specific moments during interaction of each user, where the ratio increased, which indicates moments of arousal. Table 15 gives the overview about the moments of arousal for the human operator.

TP	**Action Sequence 1 Lifiting the Table**	**Action Sequence 2 Walking Together**	**Action Sequence 3 Putting Down the Tabel**
TP1			
TP2	Constant raise before lifitng	High level of arousal during the whole carring (peak)	Constant raise during putting down
TP3	Constant raise before lifting		
TP4	No raise, constantly low	High level of arousal during the whole carring (peak)	Constant decrease during puttin down
TP5	No valid HRV data (the data transmission did not work constantly)		
TP6	Constant increase before lifting (peak)	High level of arousal during the whole carring (peak)	Constant decrease during putting down
TP7	No valid HRV data (the data transmission did not work constantly)		
TP8	Constant increase before lifting (peak)	Decrease	Constant level (rather low)
TP9	No valid HRV data (the data transmission did not work constantly)		
TP10	Constant increase before lifting (peak)	Constantly low	Constant level (rather low)
TP11	Slight increase	Increase, peak, decrease	Constant level (rather low)
TP12	No valid HRV data (the data transmission was aborted right in the beginning)		

Table 14: Overview of specific moments in the heart rate variability data of the test persons

General: peaks are mostly highest during action sequence 2, second highest in action sequence 1 as soon as the user is involved in the lifting (the heart rate variability increases during the user watches the robot while grasping the table),

Operator	**Action Sequence 1 Lifiting the Table**	**Action Sequence 2 Walking Together**	**Action Sequence 3 Putting Down the Tabel**
Test1	Increase of arousal when taking over the control, and then constant level. When moving the robot to the table, decrease.	High level of arousal at the beginning, then decrease, then increase and constant high level of arousal when turning the robot around the corner, decrease	Constant low level of arousal
Test2	Increase when taking over the control of the robot, keeping a constant medium level of arousal	Decrease to a low level of arousal. Constant raise of arousal to a high level of arousal starting when turning the robot around the corner.	Increasing to a peak, keeping that level and then constantly decreasing to a medium level of arousal when lifting down.

Test3	No valid HRV data (the data transmission did not work constantly)		
Test4	Starting at medium level of arousal increasing to a high level of arousal when taking over control. Decreasing and then constant increasing until grasping the table. Then decreasing and increasing again to a high arousal.	High level of arousal during the whole carrying (peak)	Still high level of arousal (peak)
Test5	No valid HRV data (the data transmission did not work constantly)		
Test6	No valid HRV data (the data transmission did not work constantly)		
Test7	Starting with a high level of arousal then decreasing to a minimum constantly in this level.	Constant at a mininmum level	
Test8	At the beginning constantly low. Increasing when taking over the control to a constant medium level. Slight decrease when moving the arms to the table. Slight increase when lifting	Starting with at a low level and decreasing to a minimum level of arousal. Starting to increase strongly when stopping the robot	Still increasing to a peak until the board is lifted down and then constant decrease.
Test9	Starting with a constant high level of arousal during the taking over phase. Continuing with a constant decrease. constantly increasing when robot starts walking to a medium level.	Constant medium level of arousal. Increasing to a high level when mooving close to the pillar. Slight decreasing to a constant medium level. When finished the turning constant decreasing to a minimum.	Constant minimum level of arousal
Test10	Increase, Peak after taking over the control, decrease	Medium level in the first walking period, then decrease to minimum	Peak at the beginning of action sequence, then down to a minimum
Test11	Peak when taking over the robot, decrease to a medium level, second Peak when starting to lift the table	High level of arousal during walk/carrying	Continuing high level until end of action sequence
Test12	Medium level, increase to high level alter control is taken over, raise to high level while lifting the board	From high level down to a minimum level Turing walking, approach final position raise to medium level	Peak when putting down the table

Table 15: Overview of specific moments in the heart rate variability data of the human operator

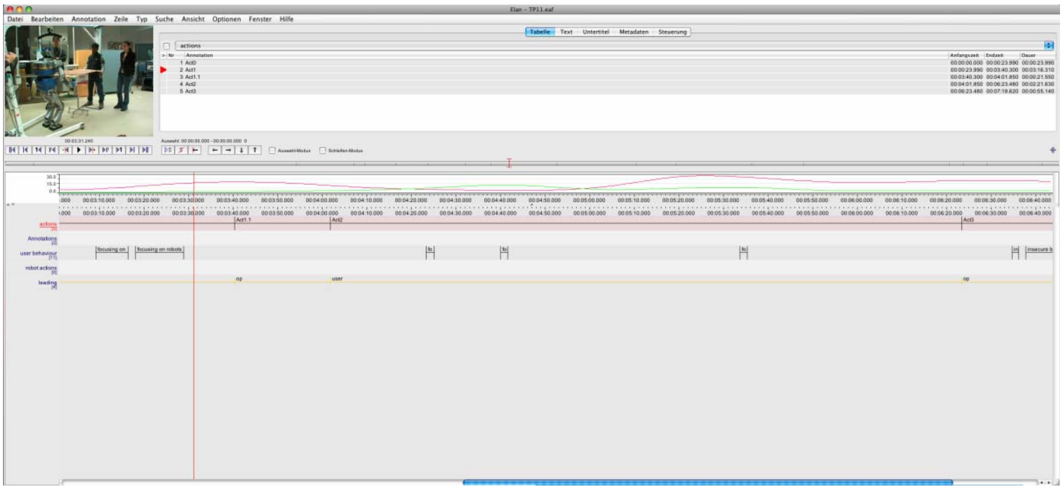

Figure 13: Heart rate variability and video synchronized for evaluation purposes in ELAN

Tele-operator Questionnaire: This questionnaire intended to measure the co-presence (scale ranges from 1: not at all to 7: very much) experienced by the human operator in Germany (OG). The average rating of co-presence is low (mean: 1.62; SE: 0.16), indicating that the tele-operator experienced hardly any feeling of co-presence.

The expert operator explained after the user study that he rated these questions low because he did not directly interact with a user but with an object, thus he rarely perceived a feeling of co-presence.

Moreover, the operator was asked how well different actors contributed to the successful task performance (scale ranges from 1: no good at all to 7: excellent). An overview of the operator's ratings can be found in Table 13, showing that the contributions of all actors were estimated as very good.

4.2.4.2 Social Acceptance Measures

NARS: Negative Attitude towards Robots decreased through interacting with the HRP-2 robot regarding all three subscales. Negative Attitude toward Social Influence of Robots (S2) decreased significantly (p=.015). The decrease of the subscales Negative Attitude toward Situations of the Interaction with Robots (S1) and Negative Attitude toward Emotions in Interaction with Robots (S3) was not significant (see Figure 14).

Significant differences between female and male participants could be found for the S1 scale (Negative attitude toward situations of the interaction with robots) before interacting with the HRP-2 robot (p=.037). Females show significantly lower ratings on this scale, indicating they have a less negative attitude toward situations in which they have to interact with robots. After the interaction with the HRP-2 robot, the rating of the females was again lower, but this difference was scarcely not significant (p=.064).

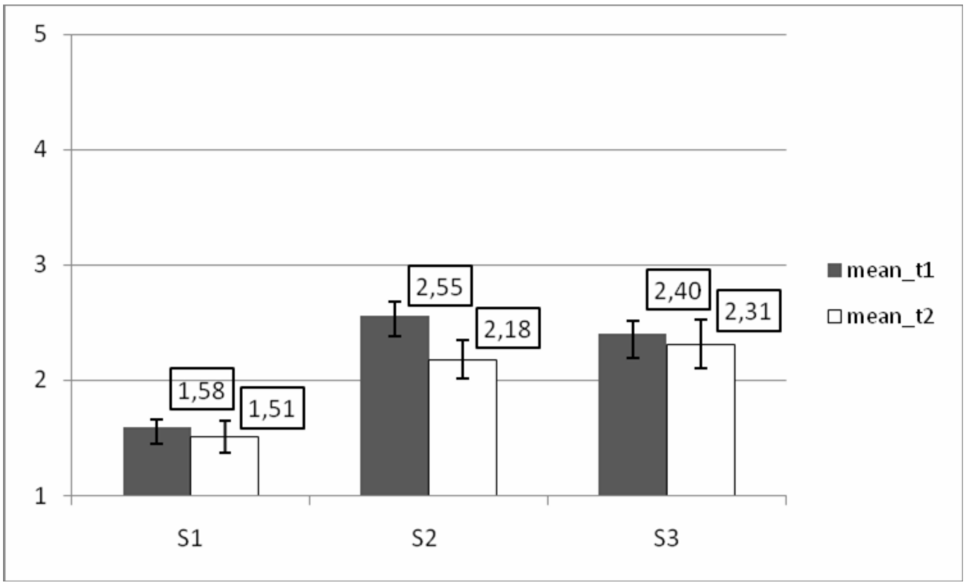

Figure 14: NARS diagram

SoAc questionnaire: The SoAc questionnaire (scaling from 1-"absolutely disagree" to 5-"absolutely agree") comprised eight indicators of social acceptance (see Figure 15). The indicator attitude towards technology (mean: 3.99, SE: 0.11) is rated highest, followed by the indicators facilitating conditions (mean: 3.71, SE: 0.10), effort expectancy (mean: 3.70, SE: 0.17) and forms of grouping (mean: 3.64, SE: 0.15). The indicator feeling of reciprocity was rated lowest (mean: 3.18, SE: 0.17), followed by attachment (mean: 3.23, SE: 0.20), self efficacy (mean: 3.40, SE: 0.17) and performance expectancy (mean: 3.41, SE: 0.19). Significant differences concerning gender could be found for the indicatorself efficacy (p=.016), as females rate self efficacy significantly higher than males.

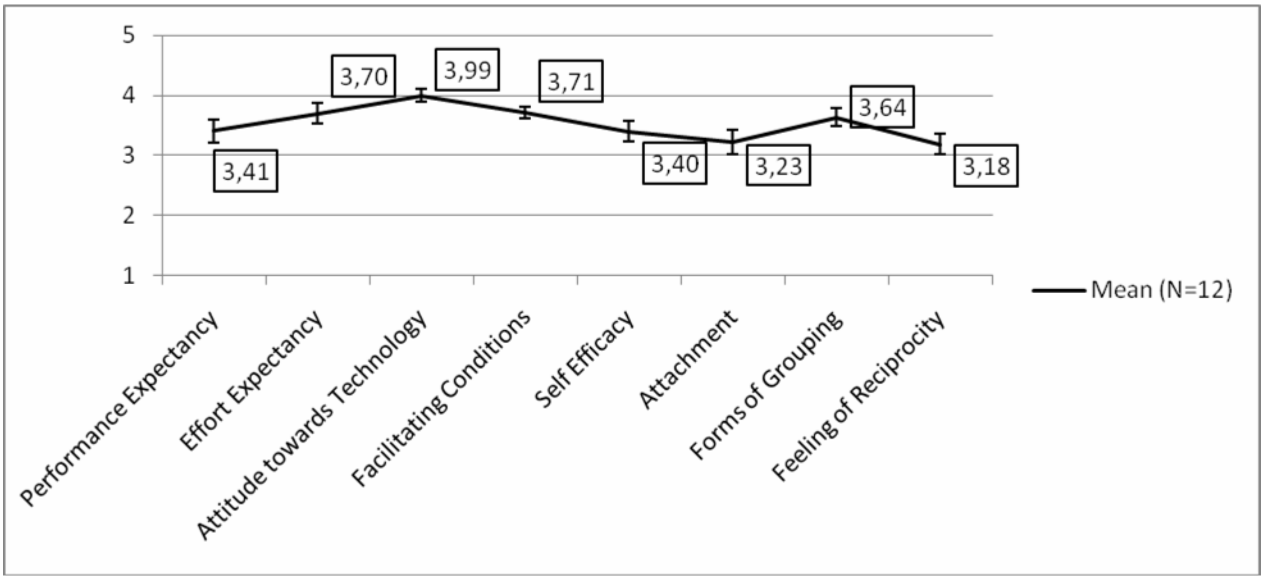

Figure 15: SoAc questionnaire indicator diagram

PANAS: Scores for Positive Affect (PA) of females range from 10 to 50 (10: no positive affect; 50: maximum positive affect). The normative PA of females is 30.62 (which means

that 50% of female normative sample have a better and 50% a lower PA score). In the final demonstrator study, the average PA of the female participants is 28.98. This corresponds to 42% of the maximum reachable PA value, which is 8% lower than the average normative female PA. Overall, 4 females have lower scores than the normative PA, and 2 have higher scores.
The normative PA of males is 32.06, with scores for male Positive Affect (PA) ranging from 10 to 48 (10: no positive affect; 48: maximum positive affect). In the final demonstrator study, the average PA of the male participants is 35.83, which corresponds to 70% of the maximum reachable PA value (20% higher than the average normative male PA). Overall, 5 males have higher scores and 1 has a lower score than the normative PA. *In sum, the male participants were more positively affected by the interaction with HRP-2 than the female participants. Compared to the normative sample, males were slightly more positively affected than average, and females were slightly less positively affected than average.*

Scores for Negative Affect (NA) range from 10 to 42 (10 means no negative affect, 42 means maximum negative affect) for both female and male participants. The normative female NA is 16.68, indicating that 50% of the participants have a better and 50% a worse NA score than 16.68. In the final demonstrator study, the average female NA is 13.85 (33% of the maximum reachable NA value), which means that 67% of the normative female sample have a higher (worse) NA score. Overall, 5 females have lower scores than the normative NA, and one has a higher score. The normative male NA is 15.2. In the final demonstrator study, the average NA of male participants is 16.17, which corresponds to 57% of the maximum reachable NA value (7% higher than the average normative male NA. Overall, 3 males have a higher and 3 males have a lower score than the normative NA. *To sum up, the female participants were less negatively affected than the male participants. The interaction with HRP-2 resulted in very little negative affect for the female participants.*

4.2.4.3 User Experience Measures

AttrakDiff: As visualized in Figure 16, participants perceived the HRP-2 robot rather positive (scale -3: negative word pole to +3: positive word pole). The Hedonic Quality – Stimulation scale (HQ-S) was rated best (mean: 1.20, SD: 0.74), which means that the participants were encouraged to interact with the HRP-2 robot. With values close to 1, Attractiveness (ATT) (mean: 1.18, SD: 0.93) and Hedonic Quality – Identity (HQI) (mean: 0.79, SD: 0.80) were also rated positive, meaning that the participants perceive the robot as attractive and identify with it. Pragmatic quality (PQ) was rated lowest (mean: 0.07, SD: 0.93), which means that the usability of the HRP-2 robot was experienced as rather neutral (neither very positive nor very negative). Participants perceived the collaboration with HRP-2 as pleasant, innovative, captivating, professional, good and novel as well as more technical than human.

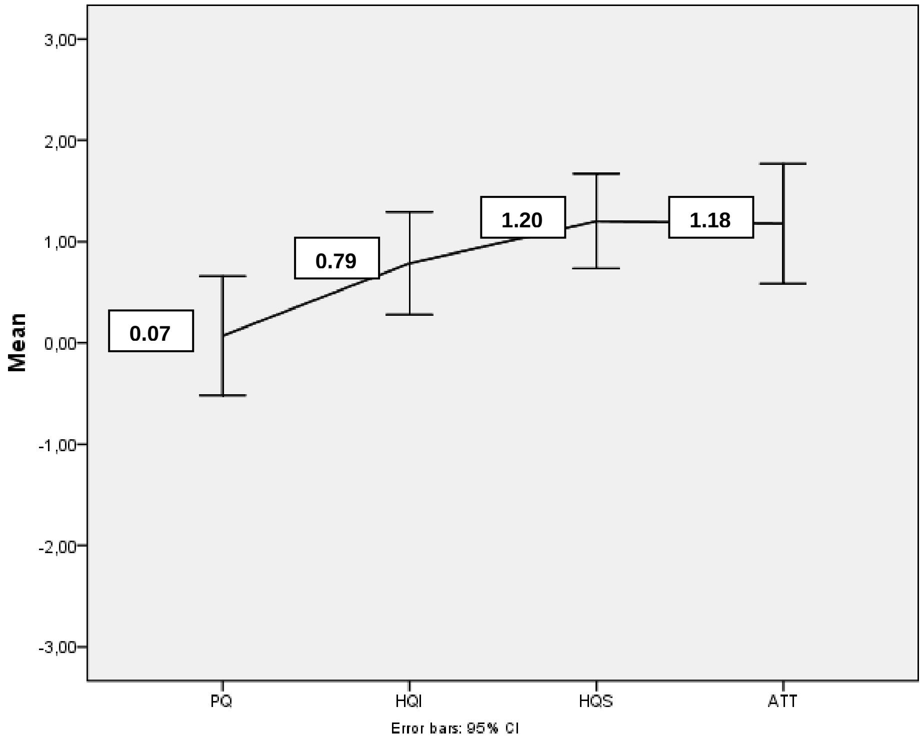

Figure 16: AttrakDiff diagram

UX-questionnaire: Figure 17 represents the mean values for the indicators of user experience (scale ranging from 1-"absolutely disagree" to 7-"absolutely agree") comprised. Participants experienced the embodiment of the robot most positively (mean: 4.22, SE: 0.59) followed by Emotion (mean: 4.21, SE: 0.52) and Feeling of Security (mean: 4.20, SE: 0.36). The indicators rated lowest are co-experience (mean: 3.88, SE: 0.38) and human-oriented perception (mean: 4.04, SE: 0.47).

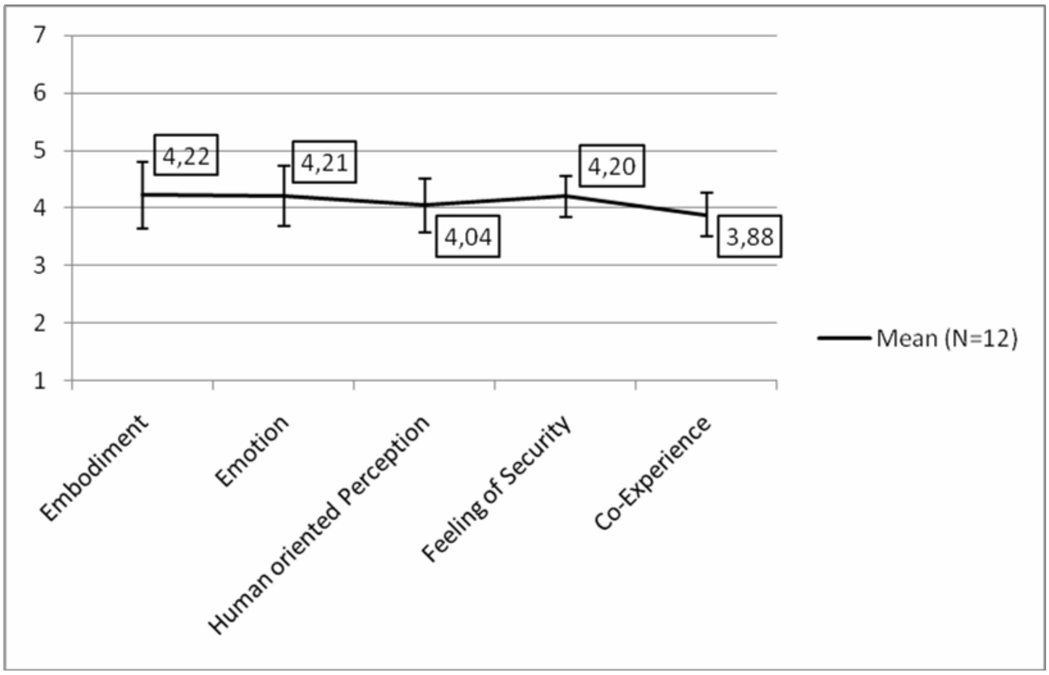

Figure 17: UX questionnaire indicator diagram

There were significant differences concerning the gender of participants, meaning that male participants rated the indicators embodiment and human-oriented perception significantly higher than females (p=.025 and p=.042).
Significant differences were also found between Western and Asian participants, as Western participants rated the indicator Emotion significantly higher than Asians (p=.030).

4.2.4.4 Societal Impact Interviews

When asking participants 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 and exhausting tasks as well as unpleasant and simple jobs. Moreover, it is mentioned that robots should do dangerous and risky jobs like those at construction or mining sites.
Areas in which robots could be introduced are for example the household, where robots could do for example the cleaning. Moreover, some participants mention monitoring and caring jobs like looking after babies or taking care of children, pets or elderly. According to them, robots would be adequate for such jobs as they can do that all the time (as they need no break). Furthermore, robots are often imagined as workers or producers in manufactories, lifting heavy things for example.
However, according to the statements of some participants, creative and complex work still needs to be done by humans. Moreover, it is often stressed that safety has first priority, followed by successful task performance. Participants also indicate that robots will be much more effective than humans. Integrating robots into working life will simplify tasks and increase productivity. One participant also emphasizes possible problems in human-robot interaction. He thinks that it is necessary for people to know exactly how the robot will behave and what to expect.

When discussing possible changes in life due to the integration of robots into a construction area, most participants indicate the there will be less injuries and a lower accident rate, as robots can work in unsafe or extreme conditions (e.g. too hot/cold, bad light, dangerous situations). Thus, more safety at the workplace will be a consequence of robots which are integrated into a construction area.
Another consequence will be higher productivity, as robots will work faster and do not need any breaks. Thus, working life will mainly change in terms of efficiency and effectiveness.
Participants also state out that costs will be lower and life will be more convenient and easier due to robots.
However, possible risks when introducing robots at the workplace are also mentioned, like, for example, the fact that somebody could be hurt when collaborating with robots. Another negative consequence mentioned is that unemployment will increase and that work will be shifted
According to one of the participants, robots need to be more sophisticated, i.e. robot should understand one’s feelings, otherwise the robots cannot take care of him. Finally, the fact that work will be shifted is often mentioned in the interviews.

Most participants think that the usage of robots in the working context requires a change of the educational system. Many of the interviewed participants are of the opinion that it is necessary to learn how to control and use robots and that therefore different education measures will be required, in school as well as at work. For example, robotic lessons in primary school (similarly to computer lessons) are necessary. Moreover, specific courses for

specific robots (similar to computer software courses) should be offered. However, some participants indicate that children will not need special courses on robotics, as they will grow up with robots and thus learn how to use them (similarly to computers). Other participants agree that specific educational measures are necessary for successful human-robot collaboration, however they also stress that another important thing is to develop robots which are intuitive for humans.
Some participants state out that rules how to interact with robots or robot usage conventions are necessary for the future. One participant mentions that in future, robots will do simple work and humans will do more intelligent work. In order to support this development, the education structure should change.

When asking participants how they imagine the societal support of using robots in the future, the fear of losing jobs is often mentioned. Some think that people are already prepared for a world with robots in everyday life through media and literature, others have an opposed opinion and indicate that society will rarely support robots. According to one participant, developed countries like Japan are early adopters of robots, whereas central Asia and Africa will adopt robots late.
Furthermore, participants think that a clear distinction between a human and a robot is important. Some participants declare that nobody knows what happens when robots have their own emotions or can think by themselves. This could also make the preciousness or definition of life more complicated for children.
Participants also indicate that guidelines on how to use robots and changes in law are necessary in a future robotic society.
The fact that people will not easily accept robots in society is also mentioned often. Some participants suggest advertising the benefits of robots in order to increase people's acceptance. Moreover, participants indicate that helpful robots doing dangerous tasks or supporting disabled people are accepted more easily by many people. The costs of a robot, especially the cost-benefit proportion, will influence the acquisition of robots.

4.3. Group-based Cognitive Walkthrough

4.3.1 Study Setting

In order to identify problems concerning learnability in human-robot interaction in two of the three[1] use cases of ROBOT@CWE, a group-based cognitive walkthrough was conducted. Details on the two user studies used for the walkthrough can be found in D3.4-7@M30.

The following research question was addressed:

How to improve a robotic system in terms of learnability?

4.3.2 Instruments

For each task of the user studies (see D3.4-7@M30) a separate cognitive walkthrough was conducted at the University of Salzburg. It was organized and moderated by a researcher from

[1] The third use case (see D3.4-3.7, section 4.5) deals with a remote control task (navigating HOAP-3 via remote control). Because previous studies showed that a group based cognitive walkthrough is not applicable for investigating human-robot interaction via remote control (see section 4.4), this use case was excluded from the Cognitive Walkthrough. Due to the fact that the remote control which is intended to be used for controlling all robots of the project was evaluated thoroughly in seperate user studies (see section 4.4 in this Deliverable, and section 10.7 in D3.4-3.7), an expert evaluation of the third use case was omitted.

PLUS, with a group of four experts from the field of HRI participating. Each session lasted about two hours. An assistant took notes during the whole procedure (see Figure 18).

4.3.3 Procedure

At the beginning of each session, the moderator introduced the experts into the scenario. Each participant received a scenario card (see Figure 18) with a detailed description of the scenario as well as two tasks which had to be analyzed together by the expert group. For the actual walkthrough, each task was divided into actions. A video of an ideal performance was used to provide information on the interaction. The evaluators went through each step necessary by watching a video clip and discussing if and why a user would choose the correct action at each step. The transcript of the sessions was analyzed and the results summarizing cognitive effort and possible problems of each step within the task were collected (see Annex).

Figure 18: Study setting (left) and task card (right) used for the cognitive walkthrough

4.3.4 Overview of Results

Problem	HRP-2	HOAP-3	Resulting Recommendation
No information on status of the robot	X		Rec 1
One-dimensional feedback (not multimodal)	X	X	Rec 2
Not feedback from the robot at all	X	X	Rec 1, Rec 3
No predictability of robot action	X		Rec4
No information on the vision field of robot	X		Rec 4
Low flexibility	X	X	Rec 5
No options of stopping or cancelling an action	X	X	Rec 6
No possibility to start interaction/an action		X	Rec 6
Unclear output from the robot +phrases +body language +light cues		X	Rec 7

Table 16: List of problems identified at the cognitive walktrough

Based on the results of the cognitive walkthrough (see problem list of Table 16), we developed a set of design recommendations for supporting learnability of the investigated HRI scenarios. As theoretical base, we took the definition learnability from Dix et al. (2003). According to the authors, learnability deals with *the characteristics of an interactive system that allow novice users to understand how to use it initially and attain a maximal level of performance*. For describing learnability in detail, Dix et al. (2003) define five principles which affect learnability. These principles are Predictability, Synthesizability, Familiarity, Generalizability and Consistency. Recommendations for improving certain aspects/principles of learnability are listed below.

4.3.4.1 Design Recommendations for Learnability in HRI (focusing on collaboration with robots)

Recommendations concerning synthesizability and consistency:
Giving feedback is related to the principle of synthesizability, enhancing learnability in a positive way. Synthesizability should give support for the user to assess the effect of past operations on the current state. Consistency is a further principle affecting learnability, dealing with the likeness in input-output behavior arising from similar situations or similar task objectives.

- ***Rec 1: Provide visual feedback about status of the robot***

It is essential for the user to know the robot's status at every point of interaction. Therefore, cues for understanding whether the robot is activated / is in a mode of receiving commands / executing any commands have to be provided.
Visual feedback via light (on the head, shoulders, in the eyes), body language, gaze direction, gestures and posture could be used for indicating the status of the robot.
For example, an inactive robot looks down, whereas an activated robot looks into the user's direction. The advantage of visual feedback is that it is understood easily and intuitively by the users.

- ***Rec 2: Provide multimodal feedback***

One feedback modality is often not sufficient for getting clear and unambiguous feedback. More information about the robot's current status could be provided for example by accompanying movements or gestures.
For more details concerning this issue, see below Rec 2a.

- ***Rec 2a: Support auditory feedback by other feedback modalities***

The understanding of auditory feedback must not be crucial. Especially when a robot uses auditory feedback, this can pose problems. For example, if the noise level of the environment is high, the verbal output of the robot can be difficult to understand.
Therefore, other feedback modalities should enhance the auditory feedback.

- ***Rec 3: Provide consistent feedback***

The robot's behavior should be consistent and unambiguous (e.g. eyes have to be illumated every time the robot is active). Furthermore, if there is multimodal feedback, consistency of the different output channels /feedback modalities has to be ensured. Moreover, response times of the robotic system must not be too long, otherwise the user cannot correlate his actions with the system's reactions. Unnecessary feedback/information should be avoided as it distracts the user. Giving immediate and relevant feedback thus supports learnability. In order to provide coherence, feedback should not only be given in case of success (of an action), but also in case of failure.

Recommendations concerning predictability:
Predictability is a principle which affects learnability. It means that there should be support for the user to determine the effect of future action based on past interaction history.

- ***Rec 4: Inform about the robot's perspective***

For a human interacting with a robot, it is not always clear how the vision of a robot works and which objects can be seen or recognized by the robot. For example, objects that are too close to the robot might not be detected. Information about the robot's perspective/vision range could be given by an ambient display, giving information about the robots field of vision. This helps the user in learning to evaluate the robots vision field correctly and in turn supports efficient interaction with it.

Recommendations concerning familiarity:
Familiarity is a principle of learnability, saying that the extent to which a user's knowledge and experience in other real-world or computer-based domains can be applied when interacting with a new system.

- ***Rec 5: Allow flexibility in interaction***

A robot should be flexible concerning the sequence of actions, the input modalities and the length of the feedback.
Flexibility in the sequence of actions means that some steps of one sequence of steps can be skipped if they are not necessary in the interaction.
The input modalities for controlling a robot should also be kept as flexible as possible, meaning that the user can select one of several different input modalities. For example, when collaborating with a robot in a factory, switching between controlling the robot with verbal input or a remote control can be beneficial depending on the situation. Generally, verbal input is faster and does not require any devices (both hands are free). However, if there is a lot of ambient noise, controlling the robot via remote control can be more efficient.
The length of the feedback given by the robot should be reduced to a minimum. Only feedback which is informative for the user should be given. Needless information / feedback should be avoided, as it is distracting and time-consuming for the user. The possibility to skip certain steps should be provided in order to shorten interaction times for more advanced users.
When interacting with a new system, novice users often rely on the principle of trial and error. In case of error, the system has to react accordingly and give feedback about the error. In order to enable trial and error, it is necessary to let the user control the situation (and not the robot).
Flexibility accounts to the principle of familiarity in so far, as the user can adapt the system's behavior that becomes familiar for him/her.

- ***Rec 6: Provide distinct possibilities for controlling the robot***

Stopping the robot, cancelling a current task / action of the robot as well as putting the robot in stand-by state should be always provided for controlling a robot. These actions are familiar for the user and are therefore easy to understand and learn. It is important to provide the possibility to stop or cancel wrong actions. The difference between stand-by and activation must be clear and unambiguous. Automatic stand-by after certain time is especially important due to safety reasons.

Recommendations concerning generalizibility:
Generalizibility is a principle of learnability, saying that there should be support for the user to extend knowledge of specific interaction within and across applications to other similar situations.

- ***Rec 7: Support easy commands***

In order to support the principle of generalizibility and in turn enhance learnability, commands have to be short, easy to remember, unambiguous and consistent. Therefore it is essential to use verbal cues and commands which are familiar and common for humans. For example, activating a robot by saying its name is intuitive for the human user, as this is also a common practice in human-human interaction. When controlling the robot verbally, possible interferences have to be taken into account. For example, efficient control of the robot is strongly dependent on the robot's position in relation to the users' position.

5. Conclusions on the Factors of the USUS Evaluation Framework

The variety of tests conducted according to the USUS evaluation framework of ROBOT@CWE have led a great amount of data on usability, social acceptance and user experience issues of different robotic systems in different scenarios as well as on societal impact. In the following chapter we will try to extract and outline the most important findings on these four factors. We therefore resort to the five main research questions defined in D1.3@M6 and will try to answer them and thus give an overall understanding of the importance of the factors within human-robot interaction.

5.1. Conclusions on Usability

Usability as a concept is composed by a number of different indicators; in particular relevant for human-robot interaction in collaboration settings efficiency, effectiveness, learnability and robustness were assumed (for definition and details of these indicators, see D1.3@M6). Furthermore utility has an impact on the overall usability.
Five research questions were defined in D1.3@M6 to guide evaluation activities. Within this document we return to these main questions and seek to answer them for the investigated robotic systems and collaboration tasks.
As we observed that the usability issues of interaction via HR interface and direct interaction via vocal communication and direct manipulation are different, we separated these two approaches where possible.

Are the means of interaction provided by the interface effective for the human and the robot? (Usab 1 – Effectiveness)
When interacting with robots of the ROBOT@CWE project in a tele-operation mode, the measured effectiveness was strongly related to the graphical user interface. Therefore notions and knowledge from the research area of Human Computer Interaction play a bigger role. The user study at UC3M showed that it is possible to control the basic functions of a humanoid robot very effectively through the human-robot interface and that the low functionality supports the user's learnablity in terms of cognitive load.
For the HR interface designing new functions could solve usability problems and increase the effectiveness. In general, for both HR interfaces an important issue for a high effectiveness is the view of the camera. A smaller display size reduces the effective control of the robot.
Collaborating with a robot by direct interaction with vocal communication or direct manipulation was used in four studies and proved successful. Speech control was used in the preliminary user study with HRP-2, the HOAP-3 study at UC3M and EPFL and the mixed reality simulation at the University of Applied Sciences of Salzburg. Natural language was perceived as an effective means of interaction but was effected because of the strict activity and response program that is required for solving a task. Due to this limitation, it is difficult to realize shortcuts with speech input, e.g. skipping a command is not yet possible.
In the mixed reality simulation with HRP-2 a direct correlation between feedback modalities and the effectiveness was observed. Haptic feedback was perceived as most usable and effective when collaborating with the robot on physical tasks. No increases in effectiveness were observed when providing visual and haptic feedback at the same time.

In general the task completion rate of all conducted user studies was high (see Figure: , meaning that nearly all users were able to successful collaborate with the robot to fulfill a common task and that robotic interfaces designed and used within ROBOT@CWE were all effective for the given tasks. A summary of the task completion rates can be found in the following table:

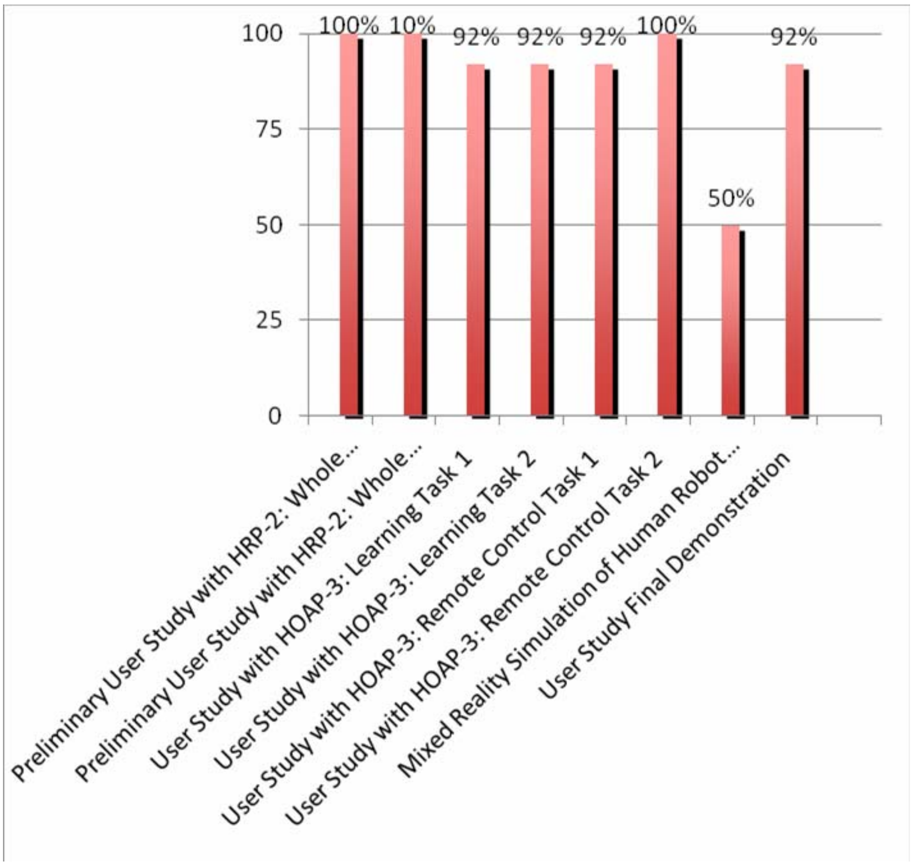

Table 17: Overview of the task completion rate of the different user studies

Are the means of interaction provided by the interface efficient for the human and the robot? (Usab 2 – Efficiency)

At the current level of robot development the user is able to control the basic functions and interact on basic level with a humanoid robot. The mixed reality study for example showed an average efficiency in the task duration, which means that the designed speech input was a good mean for interacting. However, in most of the studies the duration for completing a task varied greatly from user to user and dependent on feedback modalities. One reason might be that for the interaction with the robot, the human had to adapt to the language of the robot and could not fully exploit the advantages of natural language.

Additionally the interaction sequences in the studies with HOAP-3 and HRP-2 had a low flexibility in actions taken which has an effect on the efficiency. The users have to adapt to the predefined workflow of the robot. The efficiency of the HR interface developed by HP-EIC could be increased through additional functions, like moving the head or grab and drop an object.

The mixed reality user study showed that feedback is of great importance and revealed that because of different feedback modalities the participants' task duration and perception of the difficulty was different.

How easy to learn is the interaction with the robot for the user? (Usab3 - Learnability)
The user studies and the expert evaluations in this deliverable revealed that the most occurring and therefore major usability problem is missing or too little feedback. Both expert evaluation iterations of the HR interface as well as for the HOAP-3 tele-operation task and the group based cognitive walkthrough showed a lack of feedback. The heuristic evaluation of the HP-EIC interface for example showed that is not possible for the user to see through the HR interface that the robot is carrying an object.
Another problem for direct interaction with robots was that – due to the long time to a robot's response - the user does not know if the robot recognized the command when controlling the robot with speech input. In some cases it was not clear if the robot was ready for receiving commands.
But providing immediate, well observable and understandable feedback is an essential element for understanding and hence learning to interact with a robot. The deliverable presented some solutions for this problem. For the two user studies (HOAP-3 learning task and HRP-2 Toulouse) recommendations were developed: introducing clear and multimodal feedback and giving the users support to raise predictability.

Does the robotic interface allow enough ways for solving a collaborative task? (Usab 4 - Flexibility)
The question of whether the robotic interfaces developed and tested within the ROBOT@CWE project allow enough ways for solving a task has to be negated. Although the speech control is very natural it does not yet support different ways of solving a task. Furthermore the user is not in control of cancelling or stopping an action nor can a certain action be made undone or easily repeated. This is equally valid for all interfaces for direct interaction with a robot. Cancel or stop of the interaction is very important because the user should have a feeling security when working with a robot.
In the user study with HOAP-3 the interaction was not initiated and controlled by the user resulting in a low flexibility for the user to decide when to begin and how to further proceed in a collaborative task being carried out.
The interfaces for remotely controlling the robot offer more flexibility. They allow different possibilities in order to command the robot to an object or to get an overview of the environment.

Does the robotic interface provide enough support for the user to successfully solve a collaborative task? (Usab 5 - Robustness)
For tele-operation via interface a big issue concerning robustness was that the user is asked to set up lot things without support from the interface. For instance to select a robot, the user has to know the IP address of it. Experts evaluating the design suggested wizard mode that can help users to easily select the robot. This is important if multiple robots are available and the user has to select the desired one. Useful could be an assistant in order to guide the user through the set up of the tele-operator interface.
Persistence - a sub indicator of robustness - refers to how long an effect lasts and the capability of the user to benefit from this effect. Within the HR interface the user has to remember the ID of the object, once the robot has taken it, leading to low persistence and thus poor robustness.
Persistence is also important when interacting via vocal input. Speech input allows the user to have both arms free in order to carry an object together with the robot (as required in mixed

reality study and HRP-2 final demonstrator). If the user does not remember a specific command or does not know what step to take next, no support is provided by the robot and/or the robotic interface.

Generally robotic interfaces deployed within the project do not provide any form of support or help functionalities yet. As we assume that in collaborative working environments user will receive some kind of training support will be less crucial compared to untrained users. However, to provide robustness in the user interaction support and help issues should not be ignored.

Is it possible to achieve planned collaborative tasks with the robotic interface? (Usab 6 - Utility)
The basic functionalities of the HR interface as well as the speech input modality are sufficient in order to solve a task collaboratively. As the interfaces and interaction designs were aimed at carrying out specific, predefined tasks it is difficult to reason about the general utility of the humanoid robots used in the studies.
For the second iteration of the HR interface it can be said that the utility was increased to meet usability issues. But, increasing utility has to be done very cautiously as a higher utility can cause new usability problems. There has to be a trade off when putting more utility in such interfaces, because the greater the utility the more complicated the interaction could get.
For the direct interaction via speech control a higher utility can result in more difficulties for the user if specific commands have to be memorized. Therefore, we assume that the more natural the speech interaction is the less usability problems will be caused by a higher utility.

5.2. Conclusions on Social Acceptance

Social acceptance describes the willingness to adopt a technology and thus represents an important requirement for successfully collaborating with robots. Within the ROBOT@CWE project we assessed social acceptance of robots with regard to the following indicators of social acceptance: performance expectancy, effort expectancy, attitude towards using technology, self efficacy, forms of grouping, attachment and reciprocity. In accordance with these factors, the following research questions were investigated:

To which degree do the participants believe that collaboration with a robot improves their work? (SoAc 1- Performance expectancy)
Compared to the others indicator of social acceptance, performance expectancy is rated rather high in all user studies, meaning that participants think that collaboration with a robot improves their work. In the two user studies with HOAP-3 (remote control task and learning task), this indicator is rated highest (remote control task) and second highest (learning task).

Interestingly, non-EU citizens (compared to EU citizens), male participants (compared to females) as well as participants who have already worked in HRI and those who already participated in an HRI experiment before (compared to those who have not) expect a higher performance of robots.

We also found out that pure visual feedback reduces participants' performance expectancy. When using visual feedback in conjunction with other feedback modalities, this effect vanishes. We therefore suppose that using visual feedback exclusively confuses participants and thus reduces their performance expectancy.

It thus can be concluded that participants believe that collaboration with a robot improves their work. This belief is stronger for people who already interacted with a robot, as well as for non-EU citizens and males.

To which degree do the participants believe that the collaboration with the robot is free of extra effort? (SoAc 2 – Effort expectancy)
On the SoAc questionnaire, the indicator effort expectancy was generally rated as neither very high nor very low, meaning that participants estimate the extra effort of collaborating with a robot especially high or low.
Differences in this indicator could be found concerning gender. Male participants show significantly higher effort expectancy, meaning that the effort which is necessary for successful collaboration with a robot is estimated lower by males than by females.
Interestingly, the effort expectancy of HOAP-3 is significantly higher compared to HRP-2. This means that the effort to work with HOAP-3 is expected not that high than the effort to work together with HRP-2.
Participants who have already worked in HRI or participated in a HRI experiment before also estimate the effort needed for successful collaboration with a robot as lower compared to participants who had no contact with robots before.

We therefore conclude that people think that the collaboration with robots requires extra effort, but not on a higher-than-average level. The necessary effort is estimated higher by participants who had no previous contact with robots as well as by female participants.

Will the general attitude towards technology have an influence on the collaboration with the robot? (SoAc 3 – Attitude toward using technology)
Compared to the others indicator of social acceptance, attitude is rated rather high in all user studies, meaning that participants have a rather positive attitude towards robots. In the user study with HOAP-3 (learning task) and the final demonstrator study with HRP-2, this indicator was rated highest.

Measuring attitude towards robots showed a decrease of the negative attitude towards robots after interaction. This decrease was observed in the preliminary user study with HRP-2, in the user study with HOAP-3 (learning task) and in the final demonstration user study. In the ACE field trials we also found out that people who interacted with the ACE robot had a more positive attitude towards robots compared to people who did not interact with the robot. We therefore conclude that real interaction with a robot improves the attitude towards robots in a positive way.

Furthermore we found that non-EU citizens, male participants as well as participants who have already worked in HRI or have already participated in an HRI experiment have a more positive attitude towards robots. Moreover, attitude towards robots also seems to be influenced by the age of participants: the older the participant, the more positive the attitude towards robots.

Will the self efficacy have an influence on the collaboration with the robot? (SoAc 4 – Self efficacy)

The rating of self efficacy is located around the middle of the scale in all user studies, except of the user study with HOAP-3 (remote control task), where it is rated rather low. This means that participants do neither belief that their capabilities are very low nor very high when interacting with robots.
Interestingly, females rate self efficacy higher than males, indicating that they belief more in their capabilities when interacting with robots compared to males.

Furthermore, it could be shown that attitude towards robots is influenced by interaction. Real interaction with a robot resulted in a more positive attitude towards robots compared to no interaction.

Factor analysis showed that self efficacy cannot be separated accurately from the indicator facilitating conditions, meaning that the belief in one's competences is strongly influenced by the existing conditions. The strong interrelationship of self efficacy and facilitating conditions resulted in the factor perceived competence which merges the two indicators.

Interestingly, non-EU citizens, male participants, participants who have already worked in HRI and HRI experienced participants estimated their competences for interacting with a robot higher compared to EU citizens, female participants, participants who have not already worked in HRI and non-HRI experienced participants.

Thus, based on our results, we hypothesize that people with higher self efficacy/perceived competence are more willing to interact with robots. As self efficacy was measured after collaborating with the robot we moreover state that the interaction had no negative effects on participants' self efficacy.

To which degree does the participant form a group with the robot for solving a task? (SoAc 5 – Forms of grouping)
In the SoAc questionnaires filled in during the user studies, the average value of this indictor is around the middle of the scale. This means that participants do neither fully form a group/team with the robot nor that they are solving a task completely on their own.

Factor analysis showed that forms of grouping cannot be separated accurately from the indicators performance expectancy, attitude towards robots and relationship expectancy. Thus single items of forms of grouping were merged with these indicators. The new indicator relationship expectancy includes most of the original items of forms of grouping and is the most similar indicator with regard to content. We can say that non-EU citizens, male participants, participants who have already worked in HRI and HRI experienced participants expect a better relationship towards robots than EU citizens, female participants, participants who have not already worked in HRI and non-HRI experienced participants. We assume that expecting a positive relationship with robots is an important basis for forming a group and successfully solving a task in collaboration.

We thus can conclude that participants partly form a group with robots for solving a task. This grouping is more intense for non-EU citizens and males, as well as for people who already interacted with a robot.

Does the robot create a feeling of attachment? (SoAc 6 – Attachment)

Attachment was rated very differently in the user studies, with the lowest rating from all studies in mixed-reality study. Furthermore, attachment was the lowest rated indicator in the mixed reality as well as in the user study with HOAP-3 (learning task). The rather low ratings indicate that the robots used in the studies did not create a very strong feeling of attachment.

Factor analysis revealed that attachment cannot be separated accurately from the indicators attitude towards robots and relationship expectancy. Thus, single items of attachment were merged with these indicators. Relationship expectancy includes most of the original items of attachment and is the most similar indicator with regard to content. According to our results, non-EU citizens, male participants, participants who have already worked in HRI and HRI experienced participants expect a better relationship towards robots than EU citizens, female participants, participants who have not already worked in HRI and non-HRI experienced participants.
We suppose that expecting a positive relationship with a robot supports higher attachment and thus hypothesize that the robot creates a stronger feeling of attachment in people who already interacted with a robot, as well as in non-EU citizens and males.

Does an experience of reciprocity between the participant and the robot exist? (SoAc 7 – Feeling of Reciprocity)
The indicator reciprocity was rated rather low compared to the other indicators of social acceptance. In the final demonstration user study, reciprocity was the indicator which was rated lowest. Participants thus seem to experience reciprocity with the robot at a medium level, i.e. their feeling of reciprocity is not especially low but also not very high.

Factor analysis revealed that the indicator feeling of reciprocity cannot be selected from relationship expectancy and thus was merged with this factor. The results for relationship expectancy show that non-EU citizens, male participants, participants who have already worked in HRI and HRI experienced participants expect a better relationship towards robots than EU citizens, female participants, participants who have not already worked in HRI and non-HRI experienced participants.

We suppose that expecting a positive relationship is related to the experience of reciprocity. We therefore assume that reciprocity with the robot is experienced higher by non-EU citizens and males, as well as by people who already interacted with a robot.

General insights on social acceptance gained within the ROBOT@CWE project
When measuring negative attitude towards robots, our results further support the assumptions made in deliverable D3.4-7@M30. In the final demonstration user study we could also show that negative attitude towards robots decreased after interacting with the robot. We thus can conclude from our studies that real interaction with a robot decreases negative attitude and in turn increases acceptance of the robot.

Furthermore, we could show that participants were 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 functional, are not treated as equal (human) working colleagues and are not intended to substitute humans in a social (non-functional) way. Interestingly, acceptance seems to be influenced by the operation mode of the robot. Based on our results we assume that people feel more secure when a robot is remotely controlled (instead of acting autonomously).

Experts and non-experts often mentioned that a person's educational level influences his/her acceptance of robots and that the acceptance of robots is higher in Japan compared to Europe. These are interesting questions which should be investigated in future studies/projects. Furthermore, long-term studies should be conducted in order to investigate the observed effects for human-robot interaction over a longer time span.

5.3. Conclusions on User Experience

User experience plays an essential role in the process of designing products. That applies for robots too. In the ROBOT@CWE project we assessed the following five indicators that we believe are most influential on human-robot interaction: embodiment, Emotion, Human-oriented perception, Feeling of Security and co-experience.

Are "biologically inspired" designed robots perceived more positive than their "functionally designed" counterparts (UX 1 – Embodiment).
The focus group has shown that for certain tasks people prefer functionally designed robots to humanoid robots created for multiple tasks. Participants of the focus group indicated, that it is easier to be aware of the purposes of a functionally designed robot. The robot therefore more easily meets the expectations of the user, whereas humanoid robots might raise expectations that the robot cannot fulfill.
In the user studies conducted at EPFL we evidenced that especially women experience the HOAP-3 robot in a very positive way. The test participants used adjectives such as cute and nice. We did not investigate the impact of likeability on the overall perception of the robot in particular, but different research has already shown that there is a correlation between the embodiment / the aesthetics and the likeability of robotic devices. This is of specific interest when testing with prototypes that have not been mantled into their final appearance.

Contrarily, the HRP-2 robot was more often experienced as a machine. In the preliminary field study participants used the term machine to refer to the HRP-2 robot. Three users taking part in the final demonstrator study remarked that the embodiment of HRP-2 had a rather male appearance while its voice was clearly female and complained about this inconsistency in embodiment. However, the female voice was experienced as positive by two test users in Toulouse.

For the UC3M tele-operation user study it can be stated that users had difficulties in understanding the robot as an extension of their selves. In general, participants of all user studies commented more positively on the imagination of having humanoid robots as working colleagues than of have a functionally designed robot.

To what extend do emotions play a role in the HRI interaction? (UX 2 – Emotion)
The three laboratory-based user studies in laboratories as well as the two field trials with the ACE-robot, the mixed reality simulation and the final demonstrate revealed, that interacting with a robot affects the emotional status of a person.
The analysis of the PANAS questionnaire data of the two user studies with HOAP-3, the mixed-reality study and the final demonstrator with HRP-2 has indicated that the affect-score was significantly higher than the norm after users had interacted with the respective robot.

Similarly the interaction analysis of the ACE field trials and results from the think aloud used during the laboratory studies have shown that people use terms that are strongly related to emotions to describe the interaction.

However these emotions cannot only found in retrospective reflections on the interaction but can also be directly measured during the interaction. By the means of heart rate variability measures used in the HRP-2 final demonstrator we could reveal when exactly during the interaction affects occur that influence the emotional status of a user. In combination with observation and analysis of the recorded video material conclusions on the reasons of the changes in emotional status could be drawn. These changes can be interpreted as stress, caution but also curiosity.
For future studies we want to continue to use heart rate variability measures to assess the emotional states that people have when interaction with robots. This data could in a further step be used to adjust the robot's behavior to the emotions of a user. In a specific context an increasing heart rate could mean that the test person experiences fear. The robot could react to this emotion e.g. by increasing the distance between itself and the person.

Will user experience be more positive when human-oriented perception is involved? (UX 3 – Human-oriented perception)
In all laboratory based studies as well as the field trials we observed that people, once exposed to a robot, try to orientate themselves within the interaction process by human-oriented perception. Within the preliminary field study for instance people spoke louder when the robot did not process their command assuming that the robot could not hear their command. In the user study at EPFL participants assumed, that the robot would only see what the robot's "eyes" on the head can cover but did not noted additional cameras next to the robot. The mapping of the functions of a humanoid robot is clearly related to human-human communication.

Data from the UX-questionnaire backs this finding. When filling in the questionnaire after a user study participants tended to answer questions that were related to features the robot they were interacting with did not even have. Due to the humanoid appearance and human-oriented perception modalities they assumed, that other features natural to human-human communication were implemented in the robot as well.

In general, human-orient perception raises high expectancies of the users. This was clearly shown in the ACE field trials. As the robot used speech to initiate the interaction, the people expected the robot to understand, what they were saying to the robot. Human-oriented perception was criticized in think aloud process in the moment, the robot did not react as expected, for instance when the movement of the HRP-2 robot was much slower than a human being normally walks.

How to position a robot in a collaborative work environment so that human beings feel safe? In general: How can a human being be sure the robot won't hurt it? (UX 4 – Feeling of security)
In the laboratory settings it was rather difficult to evaluate the feeling of security people have when interacting with a robot. This is due to the fact that people take security issues for granted in laboratory-based settings. Participants commented that they could not say anything about security in real life as the contrast to a laboratory situation is too big. Especially the

rack the HRP-2 robot was mounted to was understood as a sign of complete security. Self-reporting measures are therefore limited in assessing the feeling of security.
Very interestingly people also assumed that robots operating in public space are safe and interaction can not cause any harm to human beings. The basic understanding of people interacting with the ACE robot in the two field trials was, that if the robot would not be secure, it would never be used in a public space.

In general the main influencing indicator to the feeling of security was the feeling of control. As long as a user had the feeling of being able to control an action, the user had the feeling of security. In the final demonstrator one user expressed insecurity when the operator was talking to robot starting actions without asking the participant whether he/ she was ready. This again shows the importance of the feeling of control user demand for feeling secure.

What kind of co-experience arises in collaboration with robots? (UX5 – Co-experience)
While differences of humanoid robots to functionally designed ones were explained within the chapter on embodiment, another substantial distinction evolves when it comes to co-experience. People can more easily imagine having a humanoid robot as a teammate than a functionally designed one. However, the predominant opinion on robots was, that they can never be on the same level as human teammates.
Nevertheless, direct interaction with the robot was often perceived as teamwork. This feeling was reduced when the interaction only consisted of giving and executing commands. In the latter the robot was more perceived like a tool.
Especially in the final demonstration and the ACE field trials people had the feeling that they had to support to robot in order to successfully solve a common task. The robot alone would not be able to do the operation.
Within a tele-operation mode that was subject to the UC3M user study, the users had the feeling that the robot was a representation of their own person. Only 15% had problems in defining the role within the scenario. The other 85% had a clear feeling of co-experience that can be described as “I can see the world through the robot’s eyes”.

5.4. Conclusions on Societal Impact

In order to identify problems and recommend corrective actions, the societal impact of robots has to be investigated. Within the ROBOT@CWE project we assessed societal impact of robots with regard to the following indicators of societal impact: quality of life, health and security, working conditions and employment, education and cultural context. In accordance with these factors, the following research questions were investigated:

How do systems have to be prepared so as to not influence quality of life, health and security of humans in a negative way?
Non-experts opinions about the future impact of robots on different aspects of life are often controversial. The questions if robots lead to social isolation of people, have negative effects on communication, have a positive effect on health and influence social relationships are answered heterogeneously. Furthermore, people are often undecided about security in human-robot collaboration. The question if robots make life safer or if it is risky to collaborate with robots often remains an open issue. Concerning the quality of life in general, most people think that robots increase the well-being of humans.
According to the experts, the most crucial issue when collaborating with robots are safety and security, i.e. to reduce risks in collaboration. Thus, security and safety have to be ensured when collaborating with robots. Next to technically ensuring security in collaboration with

robots, the citizens' feeling of security has to be increased. A feeling of security also turned out to be essential for the participants of the focus group. On the basis of the knowledge gained within this project, we assume that a feeling of security is the basis of a successful interaction with a robot.

Experts do not think that robots' will have negative effects on humans' health in the future and state out that robots will mainly positive effects on humans' quality of life. For example, they point out that life will be easier due to the introduction of robots in medical care.

When talking about societal impact of robots, the term "replacement" was often mentioned (by both experts and non-experts). Nobody denies the fact that low skilled people who are now fulfilling boring and repetitive tasks will be replaced by robots in future. However, this replacement is not always regarded negatively (some people are of the opinion that this fact results in better education and more sophisticated jobs in future). In order to prepare citizens for a successful collaboration with robots, it has to be clearly communicated that robots will never replace human relationships and that robots are not on the same level as humans. Differentiating clearly between robots and humans was also a central issue resulting from the focus group discussion. This is in accordance with the frequent opinion that robots will never fulfill the social needs of humans as well as with the role which is mostly assigned to robots in the future – the role of slaves.

How does the collaboration with robots impact working conditions and does it cause any changes in methods for employee retention?

When investigating citizens' attitude towards collaboration with robots, we observed a slight tendency towards negative effects on human workers due to the introduction of robots. This means that the introduction of robots on the workplace is rather seen as negative. Increasing competition between low-skilled people and higher unemployment rates among humans are often mentioned as negative consequences.

Experts also claim that the introduction of robots at work will mainly affect low skilled people**.** At first, robots will do physically exhausting work, meaning that the first jobs for robots will be 3D (dangerous, dirty and dull) jobs. A negative consequence of this could be increasing unemployment among low qualified workers. However, experts stress the positive consequence that human-robot collaboration will convey new kinds of jobs and more time for education. For example, jobs like supervisor or instructor of robots will evolve.

According to experts and citizens, the introduction of robots is a cost-benefit question. When robots do the same work for less money, they will be introduced in the working environment. A gain in efficiency / increase in productivity is therefore considered as the most important condition for deploying robots.

In order to ensure safety at the workplace and acceptance of robotic workers, experts recommend that robots should be introduced in (collaborative) working environments step by step. Moreover they emphasize that creating awareness that robots will not replace humans is very important.

Concluding we can say that working conditions will change due to the introduction of robots insofar that there is less physically exhausting work which has to be done by workers. As a consequence of the introduction of robots, new jobs related to robots will evolve. Another change in the working environment caused by the introduction of robots is an increase in productivity and thus leads to a competitive advantage for those who deploy robots. In order to successfully manage changing working conditions due to the introduction of robots, robots should be introduced to existing working environments stepwise, and with the awareness that they will support human work instead of replacing it.

How do new types of education have to be designed to cover the new requirements in the working life and is it important to groom workers for the new working conditions in a psychological manner?

This indicator of societal impact deals with consequences on the education due to the introduction of robots.

When asking people about the necessity of new educational measures in order to successfully interact with robots at the workplace, we mainly found indecisiveness about this question.

Although most of the participants agree on the fact that specific knowledge is required when collaborating with robots. They think that specific educational measures are needed for the collaboration of humans and robots. In particular, robotic training lessons at work are considered as a necessary educational measure for successful collaboration of humans and robots. Moreover, we observed the popular opinion that growing up with robots eases the right handling of robots. However, we found great dichotomy on the question if robots raise the educational level of humans.

Experts think that there will be no need to change the education system with an increased deployment of robots. However, they claim that employee training and specialization of universities is necessary. Moreover, they point out the increasing importance of education. Education will not only be more important in order to get a job, as lower qualified jobs will be done by robots, but also in order to raise a human’s acceptance of robots, as the educational level of a person influences his/her acceptance of robots.

We therefore conclude that there should be employee training and specialization of universities in order to successfully collaborate with robots. However, early preparation and education concerning robotics at school does not seem to be necessary. Thus, specific knowledge in relation to robotics should be acquired only when necessary for work. Moreover, we assume that introducing robots could be beneficial for the educational level of citizens. Therefore, creating consciousness about educational benefits due to robots is important to groom workers for new working conditions.

Does the use of robots causes a change of the culture, does it affect fears and goals of people and does the collaboration with robots have an unequal impact on different cultures? Does the collaboration with robots open new ways of thinking about what being human means?

Concerning questions on cultural aspects of human-robot collaboration, there is the tendency towards indecisiveness on such issues. For example, when asking if robots could develop a momentum participants showed great uncertainty about this issue.

We found out that fears are often mentioned when talking about cultural aspects of human-robot collaboration. For example, the fear that robots could develop a momentum was mentioned by people, as well as the risk that robots could hurt people. However, most participants agreed on the issue that there is no risk that robots turn against humans.

We also found out that the future imagination of robots is not that of future companions but of tools (assisting people). However, when asking participants what comes in their mind when they hear the term “robot”, most of them refer to anthropomorphic robots. This could be explained by a fact often mentioned by experts – the fact that people’s images of robotics are heavily influenced by science fiction media. Mass media thus seems to play an important role in shaping picture of robots the attitude towards robots. Even non-experts sometimes mentioned that their imagination of future robots is influenced by mass media.

Creativity is seen as the most important issue causing the difference between humans and robots. Other distinguishing indicators mentioned are biological components as well as the unpredictability of humans. This is in accordance with the opinions of the experts, who also say that robots are not capable for work that requires creativity. Moreover, they mention negotiation, persuasion, judgment and diplomacy as characteristics which are not applicable to robots. According to the experts, robots are suited best for work that requires spatial organization and preciseness.

Concerning cultural aspects in human-robot collaboration in general, experts think that cultural aspects are less important for taking robots into use. However, they state out that embodiment is defined by culture, which is obvious when comparing the embodiment of European and Asian robots. A cultural difference between Western and Asian people mentioned by experts is that the acceptance of robots is higher in Japan compared to Europe.

6. References

Basdogan, C., Ho, C., Srinivasan, M. A., and Slater, M. 2000. An experimental study on the role of touch in shared virtual environments. *ACM Trans. Comput.-Hum. Interact.* 7, 4 (Dec. 2000), 443-460. DOI= http://doi.acm.org/10.1145/365058.365082

Dix, A., Finlay, J. E., Abowd, G. D., and Beale, R. 2003 Human-Computer Interaction (3rd Edition). Prentice-Hall, Inc.

Ho, C., Basdogan, C., Slater, M., Durlach, N., and Srinivasan, M. A. 1998. An experiment on the influence of haptic communication on the sense of being together. In Proceedings of the British Telecom Workshop on Presence in Shared Virtual Environments (Ipswich, Suffolk, June 10-11).

Nielsen, J. (1994). Usability inspection methods. In Conference Companion on Human Factors in Computing Systems (Boston, Massachusetts, United States, April 24 - 28, 1994). C. Plaisant, Ed. CHI '94. ACM, New York, NY, 413-414

Scholtz, J. (2002). “Evaluation methods for human-system performance of intelligent systems.” In Proceedings of the 2002 Performance Metrics for Intelligent Systems (PerMIS)Workshop.

Weiss, A., Bernhaupt, R., Lankes, M. and Tscheligi, M., The USUS evaluation framework for human-robot interaction. In AISB2009: Proceedings of the Symposium on New Frontiers in Human-Robot Interaction (2009), pp. 158-165.

Weiss, A., Bernhaupt, R., Tscheligi, M., and Yoshida, E. Addressing user experience and societal impact in a user study with a humanoid robot. In AISB2009: Proceedings of the Symposium on New Frontiers in Human-Robot Interaction (2009a), pp. 149-157.

Weiss, A., Igelsböck, J., Wurhofer, D., and Tscheligi, M. Looking forward to a “Robotic Society”? - Imaginations of Future Human-Robot Relationships. In HRPR2009: Proceedings of the 2nd International Conference on Human-Robot Personal Relationships (2009b).

Weiss, A., Wurhofer, D., Buchner, R., Tscheligi, M., Blasi, L., and Plebani, M. Development of a teleoperator interface for humanoid robots by the means of heuristic evaluation technique. In TAROS2009: Proceedings of the 10th Conference Towards Autonomous Robotic Systems (2009c), K. Theocharis, N. Ulrich, M. Chris, and W. Mark, Eds., pp. 236–241.

Weiss, A., Bernhaupt, R., Schwaiger, D., Altmaninger, M., Buchner, R., and Tscheilig, M. User Experience Evaluation with a Wizard of Oz Approach: Technical and Methodological Considerations. In Humanoids2009: Proceedings of the 9th IEEE-RAS International Confernece on Humanoids Robotics (2009d).

7. ANNEX

7.1. Overview on average values for UX and SoAc indicators in

	HRP-2: preliminary study	HOAP-3: learning task	HOAP-3: remote control task	Mixed Reality Simulation	Final Demonstr.	Online questionnaire
UX:						
Embodiment	Mean: 5.33 SE: 0.47	Mean: 5.6 SE: 0.85	Mean: 6.29 SE: 0.25	Mean: 4.29 SE:0.19	Mean: 4.22 SE: 0.59	Mean: 4.43 SE: 0.08
Human or. Perception	Mean: 5.2 SE: 0.38	Mean: 4.77 SE: 1.49	Mean: 5.4 SE: 0.41	Mean: 3.77 SE: 0.24	Mean: 4.04 SE: 0.47	Mean: 2.83 SE: 0.07
Feeling of Security	Mean: 4.93 SE: 0.47	Mean: 5.16 SE: 0.77	Mean: 4.51 SE: 0.21	Mean: 4.72 SE: 0.19	Mean: 4.20 SE: 0.36	Mean: 3.53 SE: 0.07
Co-Experience	Mean: 3.7 SE: 0.25	Mean: 4.05 SE: 1.4	Mean: 4.08 SE: 0.43	Mean: 3.08 SE: 0.30	Mean: 3.88 SE: 0.38	-
Emotion	Mean: 5.85 SE: 0.3	Mean: 5.45 SE: 0.74	Mean: 5.68 SE: 0.23	Mean: 5.03 SE: 0.13	Mean: 4.21 SE: 0.52	Mean: 3.54 SE: 0.09
SoAc:						
Performance Expectancy	-	Mean: 3.75 SE: 0.22	Mean: 4.01 SE: 0.14	Mean: 3.55 SE: 0.17	Mean: 3.41 SE: 0.19	Mean: 3.21 SE: 0.05
Effort Expectancy	-	Mean: 3.43 SE: 0.19	Mean: 3.35 SE: 0.11	Mean: 3.75 SE: 0.13	Mean: 3.70 SE: 0.17	Mean: 3.51 SE: 0.04
Attitude tw. Technology	-	Mean: 4.08 SE: 0.18	Mean: 2.39 SE: 0.09	Mean: 3.70 SE: 0.17	Mean: 3.99 SE: 0.11	Mean: 3.38 SE: 0.05
Facilitating Conditions	-	Mean: 3.46 SE: 0.15	Mean: 3.35 SE: 0.14	Mean: 3.86 SE: 0.15	Mean: 3.71 SE: 0.10	-
Self Efficacy	-	Mean: 3.50 SE: 0.10	Mean: 2.12 SE: 0.15	Mean: 3.60 SE: 0.16	Mean: 3.40 SE: 0.17	-
Attachment	-	Mean: 2.74 SE: 0.27	Mean: 3.31 SE: 0.09	Mean: 2.21 SE: 0.19	Mean: 3.23 SE: 0.20	-
Forms of Grouping	-	Mean: 3.18 SE: 0.20	Mean: 3.12 SE: 0.13	Mean: 3.10 SE: 0.19	Mean: 3.64 SE: 0.15	-
Feeling of Reciprocity	-	Mean: 3.15 SE: 0.16	Mean: 3.15 SE: 0.23	Mean: 2.92 SE: 0.20	Mean: 3.18 SE: 0.17	-
Perceived Competence	-	-	-	-	-	Mean: 3.20 SE: 0.05
Relationship Expectancy	-	-	-	-	-	Mean: 2.45 SE: 0.04

Table 18: Overview on average values for UX and SoAc

7.2. Overview on publications addressing the USUS evaluation framework

		Factor Addressed			
Topic addressed	**Publication No.**	**UX**	**SoAc**	**Usability**	**Societal Impact**
USUS Framework	(1), (3)	X	X	X	X
HRP-2: preliminary study	(5)	X			X
HOAP-3: learning task	(7)	X	X	X	X
Mixed Reality Simulation	(4)	X			
Focus Group	(9)	X	X		
Remote Control	(8)			X	
Field Trials with ACE	(2)		X		X
Societal Impact Interviews	(6)				X

Table 19: Overview on publications within the project and addressed factors

Publications:

(1) GANCET, J., WEISS, A., TSCHELIGI, M., ILZKOVITZ, M., AND AKED, R. Human-Robot Collaboration in a Planetary Settlement Setup: Collaborative Work, Interactions Design and Human Factors. In *ASTRA2008: Proceedings of the 10th Workshop on Advanced Space Technologies for Robotics and Automation* (2008).

(2) WEISS, A., BERNHAUPT, R., TSCHELIGI, M., WOLLHERR, D., KUHNLENZ, K., AND BUSS, M. A methodological variation for acceptance evaluation of Human-Robot Interaction in public places. In *RO-MAN 2008: Proceedings of the 17th IEEE International Symposium on Robot and Human Interactive Communication* (2008), pp. 713–718.

(3) WEISS, A., BERNHAUPT, R., LANKES, M., AND TSCHELIGI, M. The USUS evaluation framework for Human-Robot Interaction. In *AISB2009: Proceedings of the*

Symposium on New Frontiers in Human-Robot Interaction (Edinburgh, Scottland, 8-9 April 2009), SSAISB (ISBN - 190295680X), pp. 158–165.

(4) WEISS, A., BERNHAUPT, R., SCHWAIGER, D., ALTMANINGER, M., BUCHNER, R., AND TSCHELIGI, M. User experience evaluation of multimodal interaction techniques in human-robot collaboration using a wizard of oz approach. In *Humanoids2009: Proceedings of the 9th IEEE-RAS International Conference on Humanoids Robotics* (2009). accepted for publication.

(5) WEISS, A., BERNHAUPT, R., TSCHELIGI, M., AND YOSHIDA, E. Addressing user experience and societal impact in a user study with a humanoid robot. In *AISB2009: Proceedings of the Symposium on New Frontiers in Human-Robot Interaction* (Edinburgh, 8-9 April 2009), SSAISB (ISBN - 190295680X), pp. 150–157.

(6) WEISS, A., IGELSBÖCK, J., WURHOFER, D., AND TSCHELIGI, M. Looking forward to a "Robotic Society"? - Imaginations of Future Human-Robot Relationships. In *HRPR2009: Proceedings of the 2nd International Conference on Human-Robot Personal Relationships* (2009).

(7) WEISS, A., IGELSBÖCK, J., CALINON, S., BILLARD, A., AND TSCHELIGI, M. Teaching a humanoid: A user study on learning by demonstration with HOAP-3. In *Ro-Man2009: Proceedings of the 18th IEEE International Symposium on Robot and Human Interactive Communication* (2009). accepted for publication.

(8) WEISS, A., WURHOFER, D., BUCHNER, R., TSCHELIGI, M., BLASI, L., AND PLEBANI, M. Development of a teleoperator interface for humanoid robots by the means of heuristic evaluation technique. In *TAROS2009: Proceedings of the 10th Conference Towards Autonomous Robotic Systems* (2009), K. Theocharis, N. Ulrich, M. Chris, and W. Mark, Eds., pp. 236–241.

(9) WEISS, A., WURHOFER, D., LANKES, M., AND TSCHELIGI, M. Autonomous vs. tele-operated: How people perceive human-robot collaboration with HRP-2. In *HRI '09: Proceedings of the 4th ACM/IEEE International Conference on Human Robot Interaction* (New York, NY, USA, 2009), ACM, pp. 257–258.

7.3. Interview Guidelines for Societal Impact with experts from DRAGADOS

General Questions:
Which aspects in your life and working life in specific will probably change most in the next 20 years? (Can you imagine things that will change and things that will not change in working live next 20 years?)
Are there any technologies that are more likely to influence our lives? (Can you think of any technologies that will affect our lives?)
Can you imagine conflicts if robots are introduced into working area? If yes, what kind of conflicts? If not, why not?

Open questions at the beginning:
Which parts of society are affected by the usage of robots? What positive and negative effects of the usage of robots can you imagine (for society)?
What does the usage of robots change in society (positively and negatively)? (If no answer: regarding quality of live, health, security, education system, culture, work)

General Robot Questions:
If you hear the term “robot”, what comes into your mind, what do you think of?
If you think of future robots, what can you imagine, which picture comes into your mind?
What is a robot for you personally? (Please tell me your definition of a robot)
Can there be identified different types?
Differences to “normal” machines?
Differences to humans?
What are objectives of an industrial robot? (Where does the usage of industrial robots aim at? What are the goals of the usage of industrial robots?)

SI 1: quality of life / health / security
Are there parts of our lives that will change, if robots are integrated into working live?
Which ones?
Why do you think so?
Is this positive/negative?

What about quality of life if robots are integrated into working live?
How will the future development of income be? How will it be distributed? What about disparity of incomes?
Can you imagine effects on social life? (What about social life?) Will robots have any effect on the way we communicate and interact with each other?

What about security if robots are integrated into working live?
Do you see any special risk concerning robots?
How to avoid these risks?
What would have to be done to minimize these risks?
What’s in your opinion the biggest risk concerning robots?

What about health if robots are integrated into working live?
Will there be any kind of influence of robots on health? (e.g. life expectancy…)
Imagine an accident happens: in which part of the production cycle is it most likely? Can you describe possible accidents? What has happened? Whose fault will it be?

SI 2: Work
Imagine: 20 years have passed - what will work at DRAGADOS look like?
- Jobs
- Tasks

What has changed positively / negatively?
- Examples
- Why?

What are the characteristics of future jobs (if robots are integrated into working life)?

- contract stability
- flexibility
- mobility
- hierarchy
- control of workload
- workers' functional mobility
- Risk factors? Chances?

Where can you imagine the usage of robots?

- working field (sectors)
- agricultural sector
- industrial
- construction
- service sectors
- home setting

In which aspects of society /social life should robots not be integrated? Where should robots not be used?

SI3: Education

Has our education system be changed if robots are introduced into working life? Are there any specific qualifications needed?
What will be the role of qualification in the future?

- Which qualifications do workers need in the future?
- Where do they get them from?
- Are they stable? Why? Why not?
- Responsibility (Whose responsibility will it be to gain these qualifications?)

Are modifications needed in the educational system?

- Amount
- Duration
- Ratio of theory and practice?

Which role will continuing education and training play in your enterprise?

- Occupational Retraining?

SI4: culture

Is there any influence of robots on culture? Is there any influence of robots on culture?
- Traditions? Does the integration of robots into working live match with our/your/western traditions?
- Recreation activities?
- Social System?
Can you imagine certain cultural aspects, which may limit/extent the usage of robots?
Which status will robots have in our society? Which roles will robots play in our society?
Will the value system change? How? Why?

Will there be displacement effects (i.e. human replaced by robots) in the next decade?
- Will they be specific to particular classes, geographical locations (countries) or jobs?
-Traditions?

Do you imagine some countries or continents using more/less robots than others? Will the usage of robots be equally distributed in Europe / on the whole world?
Will the objectives/ ends/ purposes of usage of robots be different in various countries?
Are there any countries which enhance the usage of robots more than others? Are there any cultural specific aspects which predestine the utilization of robots?

7.4. Detailed Results of Interviews with Experts from DRAGADOS (first round)

Below is a summary of the interviews with the experts from DRAGADOS (M. and E.). First, we present important general issues discussed with the experts. Next, a summary of issues related to each of the four factors of societal impact is given.

M. indicates that DRAGADOS is part of the ROBOT@CWE project because they see robotics as being in the edge of technology and they might be interested to use humanoid robots in future at DRAGADOS (they already have some robots in the construction in a factory). They want to keep an eye on recent technology developments and stay up to date what is going on in this area.
M. thinks that in the next 20 years, a main change will be that automation plays a great role (especially in construction industry). Monotonous and repetitious work done by people will be done in an automated way (by robots). Even in personal life more automation will occur. However, it is difficult to build robots that carry out every day facilities in the next 20 years, as there are still many technical problems to solve. He thinks that introducing humanoid robots into everyday life is very difficult as autonomous, intelligent and controllable systems are needed. Besides, he indicates that the mechanical parts of the robots also have to be far more advanced.
E. thinks that “there are not many possibilities to improve robots in a science fiction way”, meaning that there will not be much change in working life. However, he indicates that “there is no future without robots. There is a reality and it is coming anyway.” The only thing which can be done is to prevent humans from the risks.
Concerning the role and definition of robots, M. characterizes a robot as a machine. He thinks a robot is only intelligent for the work he has to do. Intelligence for the robots in the sense of human intelligence is “very very very far away” for him.
For E. personally, the most important aspect of a robot is artificial intelligence (“the robot can do things that humans do”).
M. thinks that the main difference between robots and “conventional” machine**s** is flexibility, i.e. “doing easily many different things”. The second difference is represented by the possibility to act autonomously, i.e. the level of intelligence.
M. imagines that robots could also be used in agriculture, doing monotonous tasks. Public transport could also be an application area for robots. He can also imagine robotic home assistants, however, he indicates that such highly developed robots will not be introduced in the near future as it takes more time to develop them (tasks are not repetitive – harder to develop robots for non-repetitive tasks). The same is true for construction sites.

SI 1: Quality of life, health and security of citizens
Concerning an influence of robots on health, M. points out that life expectancy could probably increase as robots are doing exhausting work. Robots itself will not have an influence on people's health as "harmful material wouldn't be allowed".
E. also mentions that robots will not have negative effects on human health.
E. thinks that there are influences of robots on culture as the whole communication will change, i.e. that communication between robots and people will be affected. Moreover, there will be less communication between people.
M. is of the opinion that there will be effects of robots on social life (on the communication and interaction of people). He could imagine that robots are "in the middle of interaction between human and human" and that "they will replace a lot of things at home".
E. thinks that robots will act as slaves (of humans) in future society.
E. thinks that future working life will probably be easier for some people, concerning medical aspects and the care of elderly or disabled people. For "normal" people, he thinks that robots will be similar to computers. He thinks that robots could be used for teaching, for older people and for some kind of services (restaurants, cleaning buildings/ streets).
M. indicates that some highly developed robots already exist; however, they are very expensive and therefore not affordable for the bigger part of people. In the future there will be an industry for taking care of old people as there are more and more older people. But in the near future, robots won't be able to do this.
M. thinks that robots (for elderly care) will be introduced in Japan first, and perhaps in China as well, and maybe also in Korea, i.e. generally in industrialized Asian countries. Especially in China there is a huge market for robots, as many people are living in just a few towns.
E. thinks that US, Germany and Europe in general and Japan will use robots more.
E. thinks that the purposes for using robots depend on the development of a country. All in all, he is of the opinion that "it's all about technology and money". Cultural aspects only play a minor role.
Introducing a robot on a construction site would represent a big change, as people are not used to work with robots. M. thinks that therefore robots will be introduced step by step.

SI 2: Working condition and employment
According to M., changes in society due to the usage of robots will be on the one hand that robots will do (physical) exhausting work. On the other hand, social problems will probably occur because of the fact that big amounts of people will be retired (as robots will carry out their work). This will especially affect people with a low educational level, as the work done by these people will be the work which will be adopted first by robots. In his eyes, education would be a solution to such a problem, as it lets people access higher level jobs. Robots will not only be able to do jobs which require basic skills (for example, they could also do topographical tasks), however, this will be the first and easiest tasks adopted by robots. M. concludes with the statement that robots will at first do jobs which are dangerous, (physical) exhausting and repetitious.
M. thinks that this change in society will not only be a problem in Spain but also in other countries. The only difference would be the extent of the problem.
E. thinks that there will not be any conflicts or problems due to the introduction of robots if they are introduced step by step. According to M., the lowest professional qualifications will be affected by the introduction of robots in a collaborative environment.
Concerning future distribution of incomes, neither M. nor E. foresee any big changes.
M. thinks that special risks in the collaboration with robots will be the same as today in the future. One special risk is that a robot "weights a lot and that it is moving two meters per second". Especially autonomous robots which move freely in their environment could

endanger people. Therefore he thinks that safety is the most important issue when collaborating with robots. However, making the collaboration with robots safe is often not easy to solve technically. Regarding security, M. does not have any concerns.
In accordance with M., E also thinks that there could be dangerous situation in the collaboration with robots if workers do not consider them as dangerous and come too close. He indicates that therefore controls are implemented, avoiding that people are too close to the robot.
M. thinks that robots could work everywhere in the future. However, they can only work together with humans as soon as safety in human-robot collaboration and fault-tolerance is guaranteed. Furthermore, the more advanced robots are, the more responsibility can be given to them. He also indicates that if people feel that robots are useful to them, they will get used to them and adopt them easily. He says: “I don’t think this is a problem”.
When M. is asked to imagine an accident in a collaborative environment, he tells about a human getting into the working area of a robot and getting hit by the robot. This would be clearly the fault of the human.
Robots will be used first at factories where repetitious work is done. However, drawbacks when adopting robots will be minor flexibility and the costs of their introduction and maintenance. In his opinion, these drawbacks represent reasons for retards in the introduction of robots.

SI 3: Education

M. indicates that education will become more important as soon as robots are able to replace basic skills and work massively. Higher educated people have a better chance for work then. Moreover, he assumes that low education implies low acceptance of robots (as lower educated people will be replaced by robots they probably will have a negative attitude towards robots). For employees, some kind of training would be necessary.
E. doesn’t think that the education system has to be changed if robots are introduced into working life, because children playfully learn to use new technologies. He also thinks that there is no need to teach ethics in school.
In M’s opinion, the need for specific qualifications in order to collaboratively work with a robot depends on the degree of development of the robot. Highly advanced robots will not differ from conventional working colleagues. It will be important for people to be trained about the capabilities and the limits of the robot they are collaborating with. Furthermore, M. thinks that new types of jobs will evolve with an increasing number of robots (for example maintenance of robots, instructor for robot). Three things have to be considered and provided when using robotic instead of human manpower: (1) the monetary costs of the robot, (2) the maintenance of the robot, and (3) the people who control the robot. Depending on how much the costs are for these requirements, robots will be introduced. This means that in M’s opinion, the introduction of robots in collaborative environments is a benefit-cost question.
E. thinks that the objectives of an industrial robot are that it increases productivity, decrease the price and gives workers more security as by carrying out dangerous tasks instead of them.
Concerning modifications of the whole educational system, M indicates that he does not know if there will be any changes in school. However, he is convinced that there will be changes in the university degrees as new specializations will emerge at the universities (experts in the field of robotics).
M. mentions that all employees at DRAGADOS receive courses and training. Amongst other things, they offer trainings for how to work with robots, but not for collaborative settings. However, if humanoid collaborative robots would be introduced at DRAGADOS, they would offer courses.

SI 4: Cultural context
E. indicates that the value system will change slow and steadily due to the introduction of robots. He says that "a problem could arise if the change is too fast".
M. thinks that if people benefit from a new technology, they will buy it and take it into use. ("If people think something is useful they will use it.") He does not think that culture limits the use of robots in any ways (at least in European countries).
E. also thinks that culture does not influence the use of robots.

7.5. Interview Guidelines for Societal Impact with experts from SAS

General Questions:

Which aspects in your life and working life in specific will probably change most in the next 20 years?
Can you imagine conflicts if robots are introduced into working area? If yes, what kind of conflicts? If not, why not? What positive and negative effects of the usage of robots can you imagine (for society)?

Definition of Robots:

What are the differences between a machine and a robot?
What are the differences between a human and a robot?
What are objectives of an industrial robot? (Where does the usage of industrial robots aim at? What are the goals of the usage of industrial robots?)

SI 1: quality of life / health / security
Are there parts in our lives that will change, if robots are integrated into working live?
What about quality of life if robots are integrated into working live?
How will the future development of income be?
Can you imagine effects on social life? (What about social life?) Will robots have any effect on the way we communicate and interact with each other?
What about security if robots are integrated into working live?
What about health if robots are integrated into working live?
Imagine an accident happens: in which part of the production cycle is it most likely? Can you describe possible accidents? What has happened? Whose fault will it be?

SI 2: Work
Which aspects that will limit or extend the usage of robots?
Where can you imagine the usage of robots?
In which aspects of society /social life should robots not be integrated? Where should robots not be used?

SI3: Education
Has our education system to be changed if robots are introduced into working life? Are there any specific qualifications needed?
What will be the role of qualification in the future?
Which qualifications do workers need in the future?
Are modifications needed in the educational system?

Which role will continuing education and training play in your enterprise?

SI4: culture
Is there any influence of robots on culture? Is there any influence of robots on culture?
Can you imagine certain cultural aspects, which may limit/extent the usage of robots?
Which status will robots have in our society? Which roles will robots play in our society?Will the value system change? How? Why?
Do you imagine some countries or continents using more/less robots than others? Will the usage of robots be equally distributed in Europe / on the whole world?

7.6. Detailed Results of follow-up Interviews with Experts from SAS

Below, a summary of the interviews with the experts from SAS can be found. At first, general issues discussed with the experts are presented. Then, a summary of issues related to each of the societal impact factors is given.

Generally, it can be said that there is heterogeneousness of the expert's predictions and ideas about a future society with robots. Asking the experts what they expect from robots in the next 20 years, some stated out that robots will still be controlled by humans or that people will be more qualified or that robots will do the low-skill work. Other statements pointed out that more robotic techniques will be used (e.g. robotics arms, no robots) and that very impressive things will come, as well as the emergence of more intelligent machines and more automation entering private and working life.
Regarding the role of robots in future experts have different opinions. While on expert thinks that robots will be just tools, another one tends to believe they could reach the status of pets. There is also the imagination of robots as co-workers. However, no one thinks that robots will become companions for humans, as there are, over a lot of technical issues, also a lot of ethical issues behind.

SI 1: Quality of life, health and security of citizens
In general more positive and less negative impacts of robots on quality of life were described.
First of all robots are expected to increase quality of life in leisure time. Many of the experts mention robots that support housekeeping tasks. Although they agree on the fact that people thus might have more time for other things, they expressed worries about people getting lazy.
Concerning health care experts mentioned usage of robots in surgery and the positive effect on the health care system this could have.
Security was defined as a very critical issue. Although mainly addressed in the work context it was generally seen as difficult to implement, as real life situations have great degree of complexity and can hardly be anticipated. Robots cannot be blamed for accidents, the experts agree. Thus, robots need to be supervised by a human controller. Furthermore drastic security measures are required (e.g. an immediate stop).
The experts expressed concerns with social life as well. As a robot will not be a communication device, experts are unsure about the impact on communication. But they are sure that robots are not going to take on the role of human beings (companions), as communicating with robots will always be less sophisticated than with a real person. Robots will thus never be a substitute for a human relationship. It´s more likely robots could serve as a kind of pet. However, experts still fear that robots could amplify social isolation.

SI 2: Working condition and employment

The introduction of robots will not have any negative impact on the employee situation of humans, as non experts fear. The experts foresee a positive effect on the working conditions, a lot of new jobs will be created through the introduction of robots; people will engage more in education and as a consequence be able to fulfill more sophisticated jobs.

The experts did not see robots on the same level as humans, and referred to the realms of subtle things that make a workplace work (e.g. unwritten rules and procedures or social roles) and stress the strong need of human workers in future.

The experts foresee the usage of robots mainly for increase of productivity or for prestige reasons. Robots will be used in production (e.g. building houses) and control (e.g. advanced alarm devices). One expert doubts if robots would be used to make the working environment safer, the “danger-argument” would just be a façade, he mentions. While other experts embrace the usage of robots in dangerous environments and the usage of robots for rescue. One expert emphasizes that robots will increasingly find their way into the people´s homes and everyday lives in future.

Opinions differ on the occupational aptitude of robots for creative work. Robots could even do artistic work, says one expert, while another one states, robots will always stay assistants; they cannot fulfill jobs where you need feelings and your brain.

SI 3: Education

The experts from SAS agree with the experts from DRAGADOS: robots should be introduced step by step in order not to overcharge the workers. The introduction of robots is expected to lead to new sciences on university, as education adapts very quickly to new forms of technologies. Robotics bothers a wide variety of field. Thus, research on robotics should be carried out by interdisciplinary research teams.

The workers who collaboratively work together with robots should be trained, especially on the limitation of the robots. One expert states´: “It´s important to explain what the robot can do and what it can´t.” The training does not need to be much different from training you have nowadays in many companies: “the introduction of robots requires specific information, so that the workers know how to use the robot, you already have that”.

In contrast to naive users the experts are not of the opinion that everybody has to be taught on robotics in school as the following statement shows: “Everybody has a micro wave but probably 20% of the population knows how it´s working”. However, the experts stress that there is a need to create awareness that robots will not replace the human´s jobs.

SI 4: Cultural context

The images and future dreams of robots and robotics are heavily influenced by science fiction media (e.g. movies, novels), the experts emphasize. The culture is a defining factor for embodiment of the robots as well; one expert stated for example that a robot that is built in Europe would look completely different than a robot built in Asia. The language was mentioned as one cultural aspect limiting the usage of robots.

Partly robots are expected to have an influence on culture as well: One expert is of the opinion that robots can actively contribute to culture in future (e.g. writing a book, make music or paint pictures), another expert thinks of robots making museums more attractive for children.

In general the experts expect industrialized countries, Japan in specific, to be more ready for the introduction of robots. “There will be more elaborated robots in 5-10 years, but people will not be ready for robots, and accept them doing more elaborated tasks in Europe, in contrast to Japan, there it´s part of consciousness”, one expert states.

Another important aspect of a change in culture is the way collaboration with robots influences thinking on what being a human means. The experts have been asked to give distinction criteria between humans and robots. An interesting result is that the differences between a human and a robot are not clear; the experts provided four different answers. All except one expert use attributes and capabilities to differentiate the robot from the human, for instance the human has a "huge capability of learning and is unpredictable in contrast to the robot", or "the human is as complex as a robot will never be" but notes that science fiction media use to make people believe that robots could be as complex as human. One expert defines the difference by the help of the components stating: "the biological components the humans are made of are the difference", but also notes that future robotics will exceed this limitation as there are yet robots that make use of biological processes.

7.7. Detailed Results on Societal Impact Questionnaire with DRAGADOS Employees

SI 1: Quality of life, health and security of citizens

This indicator of societal impact deals with the question if robots have negative influence on the quality of life, health or security of people.

The mean score of the scale quality of life, health and security (mean = 2.95; SE = 0.11) (see Figure 1), consisting of 10 items, showed that people are in general undecided about this issue. This means that people neither think that robots negatively influence our quality of life, health and security nor do they think that these aspects are positively influenced by robots. Rather, they are undecided about the future impact of robots on different aspects of life.

A detailed look on the items of this scale shows that the answers of the participants are sometimes very heterogeneous. Concerning the question if future usage of robots will lead to social isolation of people, there are as many participants agreeing as disagreeing (4 out of 10). Effects on the communication between humans due to the introduction of robots are also seen controversial: 4 of the participants do not think that there is an influence on communication, and 4 indicate that robots will be effecting human communication. The question if robots have a positive effect on the health of humans is also twofold: 2 participants think that robots have a positive effect on human health, and 2 participants disagree with this statement. Moreover, this question shows the tendency of the participants to be undecided about many issues concerning societal impact of robots: Almost one third (3 out of 10) of the participants indicated to be undecided about this question, and another third (3 out of 10) did not answer the question at all ("do not know").

Some of the statements however showed clear tendencies about expected societal impact of robots: For example, there is broad agreement on the notion that robots do not make life more difficult (8 out of 10). Only one participant indicates that robots make life more difficult, and another participant is undecided about this issue. About two third of the participants also agree with the opinion that robots will increase the well-being of humans (6 out of 9). 70% of the participants (7 out of 10) think that the introduction of robots increases leisure time for humans. Only 2 participants think that leisure time is not increased by using robots. The statement that robots make life safer is also (strongly) agreed on by 60% (6 out of 10) of the participants. However, there is also great indecision about this issue, as almost one third of the participants (3 out of 10) indicate to be undecided.

Concerning the question if robots have a negative effect on the social relationship of humans, half of the participants do not think so. About one third (3 out of 10) thinks that robots have a negative effect on human relationships, and 2 participants are undecided about this issue. More than half of the participants (6 out of 10) (strongly) disagree with the notion that the deployment of robots makes people lazy; 2 participants strongly agree with this statement. More than half of the participants (5 out of 9) do not think that it is risky to collaborate with robots. However, there is also great indecision about this topic, as one third of the participants (3 out of 9) are undecided about this issue.

SI 2: Working condition and employment

The societal impact indicator working conditions and employment deals with the question if the introduction of robots on the workplace negatively affects human workers.

The mean score of this scale (mean = 3.52; SE = 0.16) (see Figure 1), consisting of 3 items and 1 additional descriptive item, shows a slight tendency towards negative effects on human workers due to the introduction of robots.

Most of the participants (5 out of 8) are of the opinion that the introduction of robots in the workplace increases the competition between low-skilled people. Two of the participants (strongly) disagree with this notion. Half of the participants (5 out of 10) also indicate that the employment of robots leads to a higher unemployment rate among humans. Interestingly, a great part of the participants (3 out of 10) is undecided about this issue.

Concerning working conditions, 70% of the participants think that robots lead to safer working conditions. Only one participant disagrees with this notion.

When asking participants for indicating of which work robots are capable of by asking them to choose terms from a list, spatial organization and preciseness were chosen most often (8 out of 10 times). Other capabilities which were often ascribed to robots were coordination and memorization (7 out of 10 times) as well as instruction (6 out of 10 times) and perceptiveness (5 out of 10 times).

Capabilities less often chosen were perfection (4 out of 10 times) and practical intelligence (3 out of 10 times). Communication capabilities (2 out of 10 times) as well as evaluation capabilities (1 out of 10 times) were only barely chosen. Capabilities for work that requires negotiation, persuasion, creativity, judgement or diplomacy was not attributed to robots at all.

SI 3: Education

As a indicator of societal impact, education deals with the question if the introduction of robots requires new types of educational measures.

The mean value of this indicator (mean = 3.33; SE = 0.15) (see Figure 1), consisting of 4 items and 1 additional descriptive item, shows indecisiveness about this indicator in general. This means that there is no clear tendency for or against educational measures to be observed.

The heterogeneity of opinions about the indicator education is demonstrated by the statement that the introduction of robots raises the educational level of humans. Equally as much of the participants (4 out of 10) agree with this opinion as (strongly) disagree with this statement (4 out of 10). Two of the participants indicate to be undecided about this issue. The notion that no additional knowledge is required when interacting with robots also does not show clear tendencies: 3 participants agree, 4 participants disagree, and 2 participants are undecided about this statement.

Concerning the need of specific knowledge when collaborating with robots, more than half of the participants (5 out of 9) indicate that this is true. 2 participants do not think that specific knowledge is necessary, and 2 are undecided about this question.

(Strong) agreement can be found on the statement that growing up with robots eases the right handling of robots (9 out of 10). Nobody indicates to disagree with this statement.

When asking participants which educational measures are necessary for the collaboration of humans and robots, 80% of the participants (8 out of 10) state that robotic training lessons at work are needed. 60% of the participants (6 out of 10) indicate that robotic lessons at school as well as robotic studies on university level are necessary. Nobody of the participants thinks that no specific educational measures are needed.

SI 4: Cultural context

The societal impact indicator cultural context addresses the question if robots cause a change of culture.

The mean value of this indicator (mean = 2.96; SE = 0.35) (see Figure 1), consisting of 3 items and 3 additional descriptive items, shows a tendency towards indecisiveness of participants on this indicator. With other words, participants are undecided or two-folded about the question if robots have an influence on culture.

4 out of 7 participants agree on the assumption that robots could develop a momentum. Only one of the participants disagrees. The fact that 2 participants are undecided and 3 participants did not answer this question ("do not know") at all shows the indecisiveness and uncertainty about this issue.

More than half of the participants (5 out of 9) indicate that there is no risk that robots turn against humans. Only 2 of the participants think so, and 2 are undecided about this.

Concerning the notion that robots can hurt people, slightly more than half of the participants (5 out of 9) (strongly) agree with this. One third (3 out of 9) does not agree, and one participant is undecided about this issue.

When asking participants about which issues cause the difference between humans and robots, all of the participants mention creativity (10 out of 10). Other differences are indicated by biological components (7 out of 10) and unpredictability of humans (6 out of 10). Complexity and capability of learning (4 out of 10 each) are also mentioned by the participants.

In future, participants see robots mainly as tools (9 out of 10), assistants (8 out of 10), and toys (7 out of 10). Robots are only barely seen as co-workers and slaves (2 out of 10 each). Nobody sees robots as companions.

When asking participants what comes in their mind when they hear the term "robot", the majority (7 out of 10) indicates to think of an anthropomorphic robot. 30% (3 out of 10) imagines a functional robot. Nobody thinks of a zoomorphic robot.

7.8. Questionnaire on Societal Impact (English version)

Please indicate how much you agree with the following questions:

	Strongly agree	**Agree**	**Undecided**	**Disagree**	**Strongly disagree**	**Do not know**
The introduction of robots in the workplace increases the competition between low-skilled people.	☐	☐	☐	☐	☐	☐
In order to collaborate with robots, specific knowledge is needed.	☐	☐	☐	☐	☐	☐
Communication between humans will not be effected by the introduction of robots.	☐	☐	☐	☐	☐	☐
Robots can hurt people.	☐	☐	☐	☐	☐	☐
The introduction of robots increases leisure time for humans.	☐	☐	☐	☐	☐	☐
It is possible for robots to develop a momentum.	☐	☐	☐	☐	☐	☐
Due to the introduction of robots the educational level of humans is raised.	☐	☐	☐	☐	☐	☐
Robots make life safer.	☐	☐	☐	☐	☐	☐
The usage of robots will lead to social isolation of people.	☐	☐	☐	☐	☐	☐
No additional knowledge is required when interacting with robots.	☐	☐	☐	☐	☐	☐
In general, robots make life more difficult.	☐	☐	☐	☐	☐	☐
There is a risk that robots turn against humans.	☐	☐	☐	☐	☐	☐
Robots have a positive effect on the health of humans.	☐	☐	☐	☐	☐	☐
The employment of robots leads to a higher unemployment rate among humans.	☐	☐	☐	☐	☐	☐
Growing up with robots eases the right handling of robots.	☐	☐	☐	☐	☐	☐
Robots have a negative effect on social relationships of humans.	☐	☐	☐	☐	☐	☐
Robots increase the well-being of humans.	☐	☐	☐	☐	☐	☐
An introduction of robots in the workplace leads to safer working conditions.	☐	☐	☐	☐	☐	☐
The deployment of robots makes people lazy.	☐	☐	☐	☐	☐	☐
It is risky for humans to collaborate with robots.	☐	☐	☐	☐	☐	☐

Please mark the statement(s) you agree with:

Humans are different from robots because of their …

- ☐ capability of learning
- ☐ unpredictability
- ☐ biological components
- ☐ creativity
- ☐ complexity
- ☐ others: ………………………..

In future, robots will mainly be …

- ☐ assistants
- ☐ companions
- ☐ co-workers
- ☐ slaves
- ☐ toys
- ☐ tools
- ☐ others: ………………………..

Robots are capable of work that requires …

- ☐ coordination
- ☐ instruction
- ☐ negotiation
- ☐ persuasion
- ☐ memorization
- ☐ creativity
- ☐ communication
- ☐ perceptiveness
- ☐ spatial orientation
- ☐ practical intelligence
- ☐ judgement
- ☐ diplomacy
- ☐ evaluation
- ☐ preciseness
- ☐ perfection

For the collaboration of humans and robots, the following educational measure is necessary …

- ☐ robotic lessons at school
- ☐ robotic training lessons at work
- ☐ robotic studies on university level (development of new research fields)
- ☐ no specific educational measures necessary

If you hear the term “robot”, which picture comes to your mind?
(Please choose one of the answers)

☐ 

☐ 

☐ 

7.9. Video analysis of Human-Robot Interaction using Scholtz’ Guidelines

The two user studies with HOAP-3 as well as the preliminary user study with HRP-2 (see D3.4–3.7@M30) were videotaped and subsequently analysed based on the Human-Robot Interaction guidelines.

As a basis for the video analysis the following six guideline questions for evaluating human-system interaction definedby Scholtz (2002) were used.

1. Is the necessary information present for the human to be able to determine that an intervention is needed?
2. Is the information presented in an appropriate form?
3. Is the interaction language efficient for both the human and the intelligent system?
4. Are interactions handled efficiently and effectively – both from the user and the system perspective?
5. Does the interaction architecture scale to multiple platforms and interactions?
6. Does the interaction architecture support evolution of platforms?

Yanco, Drury and Scholtz adapted these questions in order to analyse human-robot

interaction. („Beyond Usability Evaluation: Analysis of Human-RobotInteraction at a Major Robotics Competition" Journal of Human-Computer Interaction, 2004). Their study was conducted at a robot rescue competition were activities of all robots, their interfaces and their operators were videotaped. The material was afterwards analyzed. As rescue robots operate in safety-critical and time-critical situations, Yanco et al. focused on time a robot-team needed to find and identify victims, the number of victims found and navigation in a difficult environment.
They developed a coding scheme to capture the number and duration of occurrences of various types of activities observed.

For analysing the videotaped information on the two user studies with HOAP-3 and the preliminary user study with HRP-2 we adapted the six guideline questions of Scholtz according to Yanco et al. As we did not examine the interaction of a human with more than one robot the question on multiple platforms was left out. Also the question on interaction architecture was no investigated.
The four guideline questions were:
1. Is the necessary information present for the operator to be able to determine whether the robot is operating correctly and that an intervention is needed?
2. Is the information coming from the robot presented in a manner that minimizes operator memory load, including the amount of information fusion that needs to be performed in the operators' heads?
3. Is the means of interaction (language) efficient for both the human and the robot?
4. Are interactions handled efficiently and effectively – both from the user and the robot perspective?

We took an information-centric view as suggested by Scholtz and developed a coding scheme covering different actions and events:

- Total time needed
- Successful completion of the task
- Mistakes made by test person
- Difficulties in communication
- Intervention/help of the test conductor

Difficulties in communication between the human and the robot where subdivided into four categories: (1) the robot does not respond to a command, (2) the robot does not understand the given command, (3) the robot misinterprets the command and (4) the robot cannot execute the command though conditions are accurate.

Results

Preliminary user study with HRP-2

<u>Task 1 (Command the robot to find and grasp the orange ball):</u>

4 of 4 participants completed the task.
Average time spent: 3:33 min (min. 2:44, max. 8:32)
2/4 Participants made mistakes, each 2 times
- 1x give the wrong command
- 2x doesn't say '14' to activate the robot

- 1x misses out the command ‘look down’

2/4 participants ask the experimenter for help

Human-robot communication:
2/4 participants: Robot does not respond to a command (each once)
2/4 participants: Robot misinterprets command (1x robot turns into wrong direction, 1x robot moves head instead of body)
3/4 Robot cannot execute command though conditions are accurate (can‘t recognize the object (table))

<u>Task 2 (Command the robot to put the orange ball on the yellow table):</u>

4 of 4 participants completed the task.
Average time spent: 4:55 min (min. 2:44, max 8:32)
2/4 Participants made mistakes, each 2 times

- 1x give wrong command
- 2x doesn’t say ‘14’ to activate the robot
- 1x misses out the command ‘look down’

2/4 participants ask the experimenter for help

Human-robot communication:
2/4 participants: Robot does not respond to a command (each once)
2/4 participants: Robot doesnot understand a given command (2x robot understands purple ball‘, 1x robot can‘t see any table)
1/4 participants: Robot misinterprets command
1/4 Robot cannot execute command though conditions are accurate

User study with HOAP-3: Learning task

<u>Task 1 (Teach the robot to push the box)</u>

10 of 12 Participants completed the task.
Average time spent: 4:43 (min. 1:59, max. 10:45)

Repetition of Demonstration (sequence 2): 3.67,

Repetition counts range from 1 to 11
6/12 participants were always satisfied with their demonstration

Repetition of HOAP-3 doing the task (sequence 3): 3.08,

Repetition counts range from 1 to 12
2/12 were not satisfied with final outcome
08/12 participants get assistance from the experimenter
4/12 participants made the mistake of not saying start

Human-robot communication:
5/12 participants the robot didnot react to a command (4x cannot recognize task card – no reaction, 1x robot doesnot wait for answer and starts repetition)
5/12 participants robot cannot execute command (2x “the thing I saw disappeared, (2x aborts demonstration, 1x cannot see target)

<u>Task 2 (Teach the robot to close the box)</u>

11 of 12 Participants completed the task.
Average time spent: 3:38 (min. 2:92, max. 6:35)

•Repetition of Demonstration (sequence 2): 2.92,

Repetition counts range from 1 to 8
7/12 participants were always satisfied with their demonstration*

•Repetition of HOAP-3 doing the task (sequence 3): 2.67,

Repetition counts range from 1 to 5
2/12 were not satisfied with final outcome
6/12 participants get assistance for instructor
3/12 participants made the mistake of not saying start

Human-robot communication:
2/12 participants the robot did not react to a command (4x cannot recognize task card – no reaction)
2/12 participants: robot misinterprets command (1x participant says yes, robot does no, participant says no, robot does yes)
5/12 participants robot cannot execute command (5x cannot see target)

User study with HOAP-3: Remote control task

Task 1 (Navigate robot from point A to point B)
Average time spent on the task: 5:55 min (min. 4:41, max. 11:07)

Task 2 (Help the robot recognize an object)
Average time spent on the task: 0:49 min (min. 0:17, max. 3:02)

Due to remote controlling of the robot via a GUI no extensive analyses concerning difficulties in Human-robot communication using Scholtz guidelines was conducted for the remote control tasks.

User study with HOAP-3: Learning Task 1

Participant	Duration	Task completed	Number of repetition of demonstration	Satisfied after the demonstration	Number of robot's demonstrations	Satisfied at the end of the task	Mistakes made by participants	Description of the mistake	Robot's status unkown of the participant	Difficulties in Human-robot communication				Help provided by the instructor
										1	2	3	4	
1	2:52	yes	3		2	No	0		after failure - status of process unknown - TP does not know which command to give	0	0	0	0	0
2	2:49	yes	2	1	2	yes	1	TP tries to move arm without "start"-command		1	0	0	1	0
3	10:14	No	4	1	4	No	0		No instructions from robot of "Lets start the demonstration; robot can't push box as his arm is above, turns to demonstration mode					1
4	1:59	yes	1	1	2	Yes	0			1	0	0	0	1
5	5:02	yes	5	2	2	yes	0		robot skips question of satisfied with demonstration and starts with demo again	2	0	0		1
6	3:04	yes	3	1	1	yes	0		robot cannot identify card, person waits for quite a long time	2	0	0	0	0
7	5:28	yes	4	3	3	yes	2	TP doesnot say "start"		0	0	0	1	3
8	3:46	yes	4	1	1	yes	1	TP doesnot say "start"	TP doesnot know if to put task card or box in the beginning, robot doesnot say anything	0	0	0	0	2
9	5:30	yes	5	4	4	yes	0		after aborting repetition robot doesnot react	0	0	0	0	0
10	2:44	yes	1	1	2	yes	0			0	0	0	2	1
11	2:24	yes	1	1	2	yes	1	TP doesnot say "start"		0	0	0	1	1
12	10:45	yes	11	7	12	yes	0		Robot aborts repetition and restarts it; Robot performs repetition a second time without asking	0	0	0	0	1

1: the robot does not respond to a command; 2: the robot does not understand the given command; 3: the robot misinterprets the command; 4: the robot cannot execute the command though conditions are accurate

User study with HOAP 3: Learning Task 2

Participant	Duration	Task completed	Number of repetition of demonstration	Satisfied after the demonstration	Number of robot's demonstrations	Satisfied at the end of the task	Mistakes made by participants	Description of the mistake	Robot's status unkown of the participant	Difficulties in Human-robot communication				Help provided by the instructor
										1	2	3	4	
1	4:05	yes	3	3	3	No	0			0	0	0	0	0
2	3:56	yes	2	2	2	Yes	0		TP tries to move arm after robot says "lets start the demonstration"; Robot can not see target, TP does not know what to do	0	0	0	1	2
3	1:55	yes	1	1	2	yes	0			0	0	0	0	0
4	2:57	yes	2	1	2	yes	0					1	3	1
5	2:49	yes	2	1	3	yes	0			0	0	1	1	0
6	1:38	yes	1	1	1	yes	0			0	0	0	1	0
7	4:02	yes	3	2	2	yes	1	TP doesnot say "start"		1	0	0	0	1
8	3:27	yes	2	2	3	yes	0			2	0	0	0	1
9	2:19	yes	2	1	1	yes	0			0	0	0	0	2
10	6:35	yes	5	5	5	yes	3	TP doesnot say "start"	Robot waits for start TP does not know what to do	0	0	0	3	0
11	4:01	yes	4	4	4	yes	0			0	0	0	0	0
12	10:45	no	8	4	4	no	1	TP doesnot say "start"		0	0	0	0	1

1: the robot does not respond to a command; 2: the robot does not understand the given command; 3: the robot misinterprets the command; 4: the robot cannot execute the command though conditions are accurate

Preliminary user study with HRP-2: Task 1

Participant	Duration	Task completed	Mistakes made by participants	Description of the mistake	Difficulties in Human-robot communication 1	2	3	4	Help provided by the instructor
1	05:36	yes	2	gives wrong command; does not say fourteen	1	0	2	2	0
2	05:11	yes	2	does not give command look down (2x)	1	0	1	1	1
3	02:23	yes	0		0	0	0	0	0
4	02:24	yes	0		0	0	0	1	1

1: the robot does not respond to a command; 2: the robot does not understand the given command; 3: the robot misinterprets the command; 4: the robot cannot execute the command though conditions are accurate

Preliminary user study with HRP-2: Task 2

Participant	Duration	Task completed	Mistakes made by participants	Description of the mistake	Difficulties in Human-robot communication 1	2	3	4	Help provided by the instructor
1	5:30	yes	2	gives wrong command; does not say fourteen	1	0	0	3	0
2	2:44	yes	0		1	1	0	0	0
3	02:57	yes	2	does not say fourteen; does not give command look down	0	0	0	0	0
4	08:32	yes	0		0	2	2	0	1

1: the robot does not respond to a command; 2: the robot does not understand the given command; 3: the robot misinterprets the command; 4: the robot cannot execute the command though conditions are accurate

User study with HOAP-3: Remote control task 1 and 2

Participant	Duration Task 1	Task 1 completed	Duration Task 2	Task 2 completed
1	6:57	yes	0:24	yes
2	11:07	yes	3:02	yes
3	8:46	yes	0:58	yes
4	5:23	yes	1:03	yes
5	7:50	yes	0:35	yes
6	4:41	yes	0:27	yes
7	4:55	yes	0:39	yes
8	5:00	yes	0:17	yes
9	5:17	yes	0:20	yes
10	6:10	yes	0:17	yes
11	9:56	yes	0:44	yes
12	10:40	no	2:14	yes

7.10. Online questionnaire of the final Japan experiment

To what extent, if at all, did you have a sense of being with the other person?

not at all very much no answer
1○ 2 ○ 3○ 4○ 5○ 6○ 7○ ○

To what extent were there times, if at all, during which the Human-System Interface (haptic interface) seemed to vanish, and you were directly working with the other person?

not at all very much no answer
1○ 2○ 3○ 4○ 5○ 6○ 7○ ○

When you think back about your experience during the experiment, do you remember this as more like just interacting with a robot or working with another person?

robot person no answer
1○ 2 ○ 3○ 4○ 5○ 6○ 7○ ○

To what extent did you forget about the other person, and concentrate only on doing the task as if you were the only one involved?

not at all very much no answer
1○ 2 ○ 3○ 4○ 5○ 6○ 7○ ○

Think about a previous time when you cooperatively worked together with another person in order to move or manipulate some real thing in the world (for example, shifting some boxes, lifting luggage, moving furniture, and so on). To what extent was your experience in working with the other person on this task today like that other real experience, with regard to your sense of doing something together?

not at all very much no answer
1○ 2 ○ 3○ 4○ 5○ 6○ 7○ ○

During the time of the experience, did you often think to yourself that you were just manipulatinga robot with the Human-System Interface (haptic interface), or did you have a sense of being with another person?

robot person no answer
1○ 2 ○ 3○ 4○ 5○ 6○ 7○ ○

Overall rate the degree to which you had a sense that there was another human being interacting with you, rather than just a machine?

not at all very much no answer
1○ 2 ○ 3○ 4○ 5○ 6○ 7○ ○

Please give your assessment of how well you contributed to the successful performance of the task.

not good at all excellent no answer
1○ 2 ○ 3○ 4○ 5○ 6○ 7○ ○

Please give your assessment of how well the other person contributed to the successful performance of the task

not good at all						excellent	no answer
1○	2 ○	3○	4○	5○	6○	7○	○

Please give your assessment of how well you and the other person together performed the task.

not good at all						excellent	no answer
1○	2 ○	3○	4○	5○	6○	7○	○

Please indicate your gender.

Male ○ Female ○

7.11. Online questionnaires on UX and SoAc

User Experience
Please indicate whether you agree or do not agree with the following statements.

	strongly agree						strongly disagree	No answer
I liked the size of the robot.	○	○	○	○	○	○	○	○
I think that the robot is vulnerable to hackers.	○	○	○	○	○	○	○	○
I would be disappointed if the robot did not understand my commands.	○	○	○	○	○	○	○	○
I liked that the robot looked similar to a human.	○	○	○	○	○	○	○	○
I hesitated to use the robot for fear of making errors that will harm me.	○	○	○	○	○	○	○	○
I perceived the robot as a social actor.	○	○	○	○	○	○	○	○
I liked that the robot has human like features: e.g. face, ears, eyes etc.	○	○	○	○	○	○	○	○
I feared to use the robot as an error might harm the robot.	○	○	○	○	○	○	○	○
I perceived that the robot is intelligent.	○	○	○	○	○	○	○	○
I were angry if the robot did not understand my commands.	○	○	○	○	○	○	○	○
I liked the design of the robot.	○	○	○	○	○	○	○	○
The robot could become a companion for me.	○	○	○	○	○	○	○	○
I would feel secure when working with the robot.	○	○	○	○	○	○	○	○
I would feel afraid of the robot.	○	○	○	○	○	○	○	○
I perceived the robot as safe.	○	○	○	○	○	○	○	○

Social Acceptance
Please indicate whether you agree or do not agree with the following statements.

	strongly agree	slightly agree	Undecided	slightly disagree	strongly disagree	No answer
The deployment of robots will increase my chances of success in my job.	○	○	○	○	○	○
It will be easy for me to become skillful in dealing with robots.	○	○	○	○	○	○
Robots will make work more interesting.	○	○	○	○	○	○
Robots will be part of our everyday work.	○	○	○	○	○	○
I can imagine that I will care for the wellbeing of a robot.	○	○	○	○	○	○
I can imagine to take a robot into my heart.	○	○	○	○	○	○
Robots will have a similar importance as human colleagues.	○	○	○	○	○	○
It would feel good if a robot was near me.	○	○	○	○	○	○
I will solve tasks faster using robots.	○	○	○	○	○	○
I could not be successful while working with robots under time pressure.	○	○	○	○	○	○
Robots will make my tasks easier.	○	○	○	○	○	○
Humans and robots will be interdependent.	○	○	○	○	○	○
Interacting with robots will be easy to understand.	○	○	○	○	○	○
I would not like to work together with robots.	○	○	○	○	○	○
It would be difficult to learn how to handle robots.	○	○	○	○	○	○
I will never be able to solve a task together with a robot.	○	○	○	○	○	○
Robots will facilitate burdensome tasks we have now.	○	○	○	○	○	○
Robots and humans will make a good team.	○	○	○	○	○	○
The interaction with robots will be a mutual experience.	○	○	○	○	○	○

Using robots is a bad idea.	○	○	○	○	○	○
I would be afraid to employ robots at work.	○	○	○	○	○	○
I would be motivated to integrate robots in my daily workday.	○	○	○	○	○	○
If problems with robots occur there would be persons who could help me.	○	○	○	○	○	○
I could not solve a task with the help of robots if no one was there to tell me what to do.	○	○	○	○	○	○
I would find robots in my job useful.	○	○	○	○	○	○
It will be easy to use robots.	○	○	○	○	○	○
Working with robots would be fun.	○	○	○	○	○	○
Efforts to solve tasks together with robots will be a huge undertaking.	○	○	○	○	○	○
I could solve all problems which occurred during the interaction on my own.	○	○	○	○	○	○
I have the necessary knowledge to handle robots	○	○	○	○	○	○
I can imagine building a special relationsship with robots.	○	○	○	○	○	○
I do not think it is necessary to employ robots in daily working life.	○	○	○	○	○	○
The relationship with robots will be based on the principle of give and take.	○	○	○	○	○	○
The utilisation of robots will increase my productivity.	○	○	○	○	○	○
I would not like to imagine a world in which robots were not used.	○	○	○	○	○	○
Robots will be an important part of our society.	○	○	○	○	○	○
When a problem occurrs with robots, I would not be able to continue with my work	○	○	○	○	○	○

without help.						
I do not have the necessary abilities to handle robots.	◯	◯	◯	◯	◯	◯
I would like to collaborate with robots.	◯	◯	◯	◯	◯	◯
There will be enough information material available to help simplify the interaction with robots.	◯	◯	◯	◯	◯	◯

Sociodemographic

Please indicate your gender.	Female ◯	Male ◯						
Please indicate your age.								
Please indicate your highest finished education level.	obligatory school ◯	high school ◯	university degree ◯	No answer ◯				
How often do you interact with robotic systems?	Daily ◯	several times a week ◯	once a week ◯	several times a month ◯	once a month ◯	less ◯	never ◯	No answer ◯
Have you ever worked in the (research) field of HRI (human-robot-interaction)?	Yes ◯	No ◯	No answer ◯					
Have you ever participated in experiments involving robots?	Yes ◯	No ◯	No answer ◯					
Where do you come from?								