CogLaboration

Collaborative Project

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D6.10 Report on Evaluations methods and procedures

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Abstract

This report details the evaluation methods and procedures for the Coglaboration trials. It covers both the proposed human-human trials as well as the human robot trials. The aim of these evaluation methods and procedures is to capture sufficient data to enable the detail of the object passing task to be examined in detail. The primary assessment is a quantitative one and data is collected from a variety of sources; In the human-human trials this is primarily from motion capture systems supplemented with sensors in the object being passed, which for the human-robot trials the main source of data comes from the robot and hand sensor data but also supplemented with sensors in the object and the vision system data. This quantitative data is complemented by some qualitative data regarding the subject's impression of the object passing task.

Executive summary

This report details the evaluation methods and procedures to be undertaken within the CogLaboration trials to assess the success and fluency of the object passing task. The evaluations are carried out in two settings; Human-human object passing tasks and human-robot passing tasks. The purpose of the human-human trials is to establish both what constitutes fluency in object passing tasks between humans and to establish the key factors involved in determining success and fluency. Within the human-robot trials the main purpose is to evaluate how well the robot can achieve fluency with a cooperative human partner and to determine any areas for further improvement.

The trials will be undertaken utilising the scenarios established described within D2.10. These involve both a work situated set of tasks and a home situated set of tasks in order to fully explore a wide range of object passing task parameters. Equally, the range of tasks imposes constraints and limitations on the methods of data collection and these have been taken into account in determining the optimum evaluation methods and procedures that still give consistency across each set of trials.

Both quantitative and qualitative data will be collected and analysed to determine the success and quality of the transfer tasks. For human-human trials the primary sources of quantitative data are sensors placed within / on the object being passed and a motion capture system. The combined data from these sources allows a high definition log of the trajectory of the object to be obtained from which the time and smoothness of the passing task can be assessed objectively.

For the human-robot trials the motion capture system may not be available, although the use of a portable motion capture system is being evaluated. Nevertheless, there is potentially a lot more high quality quantitative data available from the robot arm, hand sensors and visions system. These sources will therefore be used to establish the trajectory of the object.

For both sets of trials the analysis will attempt to determine the key parameters that determine whether an object passing task is accepted as natural (i.e. fluent). These parameters include:

- The overall time of the passing task
- The time of joint contact between the party passing the object and the one receiving it.
- The velocity of approach before joint contact is achieved
- The smoothness (low acceleration and jerk) of the transfer task
- The grasp position achieved
- The forces and torques involved in the transfer task

These quantitative measures will be supplemented by qualitative measures aimed at establishing the subjects feeling as to whether the passing task felt natural or not. The primary measure will be a rating scale that is calibrated to try and minimise the inter-subject rating variability, as far as this is possible. Therer will also be a series of more open ended subject questionnaires to ensure that the subjective issues surrounding the task (such as whether the person was comfortable working near a robot) are captured and factored into the final analysis.

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Table of Contents

Abbreviations

A list of abbreviations in alphabetical order is strongly recommended. See the following example.

DoF: Degrees of freedom

FT Sensor: Force and Torque Sensor

ICT: Information and Communication Technologies

1 Introduction

This deliverable describes the evaluation procedures that will be put in place to quantify and qualify the exchanges procedures. As much as possible, a similar set-up will be used both for the Human-Human observation (realized within the work package 2) as well as for the Human-Robot observation, in order to maximize the possibilities of comparison capabilities.

The objective of the evaluation protocols defined here is to illustrate how the quantitative and qualitative measures identified during the study of the state of the art in D2.20 can be effectively observed while realizing the object exchanges related to the two scenarios defined in D2.10. In this sense, this deliverable can be seen as the intersection of the two mentioned documents. This aspect guided us to prepare and organize the work described in this document. In the next section, we will reconsider the two scenarios mentioned to highlight the related set up specifications. We will then mention the different observation tools that are to be used during the trials. Then, all the quantitative and qualitative measurements highlighted in D2.20 will be analysed to specify how they can be observed in the two scenarios defined, considering the specificities and constraints of the two agent groups that will be observed (Human-Human and Human Robot group).

2 Scenarios analysis

This section analyses the two scenarios that have been defined in D2.10, with the objective to highlight the elements that specify the evaluation set up. In both scenarios different partner's positions have been identified. We consider that these configurations are specifying the position of the human partner for the human-human evaluation and the human-robot evaluation. This person is labelled *person A*, while the second partner can be either another human, named *person B*, or the robot, called *robot*.

Although the description of the scenarios covers correctly the definition of the set-up and that the first evaluations realized during work-package 2 will enable to complete the specification, the main situations are reminded for the two scenarios.

2.1 Car Mechanic scenario

The car mechanic scenario has defined three different configurations

- Situation 1: person A lying under the car,
- Situation 2: person A working in an engine bay,
- Situation 3: person A working under an hydraulic ramp.

Good indications have been already provided in D2.10 on how these 3 situations could be simulated. Situation 1 requires a base onto which person A is lying and another one at around 500 mm to represent the underside of the car. In such situation, the person A will mainly produce human arm motions parallel to the floor, and the other partner (person B or robot) mainly observes only the arm of the partner. The height of the person lying onto the floor must be sufficient for enabling the human partner or the robotic arm to reach the exchange position. Situation 2 and 3 consider sets-up in which person A is standing up and occupied in working on different locations.

2.2 Domestic scenario

The domestic scenario involved two different configurations:

- Situation 1: person A in a standing position
- Situation 2: person A seated.

In both case the person A is considered to be in front of his partner,

3 Observation tools

This section describes the specific elements that will be used to realize the measurements, according to the criteria described in the next section. We mainly mention here the components that are not already embedded into the robotic system.

3.1 Motion capture system

The Human-Human observations taking place in Birmingham facilities will use the Qualysis motion capture system, enabling to grab the human posture along time.

We will also use the EasyTrack 500 optical motion-tracking system (Atracsys, Switzerland) in order to track the human participant's hand movement and object using active markers. easyTrack500 (Atracsys, Switzerland) is a portable 3-camera motion tracking system which tracks a series of active LED markers in parallel. The system can be controlled under C++ or Mat lab programming languages to provide real-time data streaming with an accuracy error of less than 0.2 mm. The advantage of this portable system is that it could be also be used for the Human-Robot experiments that will take place in Tecnalia's facilities.

Figure 1: Illustration of the main component of the EasyTrack500, in charge of tracking the active leds. The component can be easily mounted onto regular tripods, providing an easy installation for measurement close to the experiment settings

3.2 Sensorised object

A sensorised object will be designed to get some information about the interaction realized with it by the partners. The current object we are working on is a custom-made 3D printed symmetric plastic structure in which are mounted three 6 DoF force/torque (FT) sensors (see Figure 2). The object is13 cm in length, 6 cm in height and 2.5 cm in width at the ends and its total weight was 150 g. Pairs of participants use precision grip (thumb pad opposing pads of index and middle fingers) to grasp the sides at each end of the object indicated by a 3 cm x 3 cm square surface. Two FT sensors (ATI Nano17, USA) mounted under the grip surfaces at each end record grip force of each partner. A third FT sensor (ATI Nano43, USA) is placed in the middle of the object to record the interaction force between the two partners.

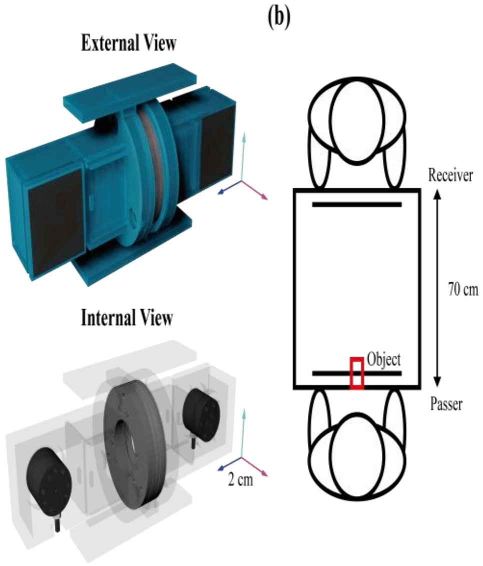

Figure 2: Drawing of the sensorised device. Each participant grasps the object on the square pads at each end.

3.3 External vision sensor

For the purpose of internal post study of the trials, some external vision system might be used to record part or all the experiments. This naturally requires the agreement of the persons participating to the trials, for ethical issue. This will be verified within the agreement sheet all partners will be firming before the observation starts. During the Human-Human observations, the vision facilities provided with the Qualisis motion capture system could be used. During the Human-Robot experiments, an external camera or webcam could be used. Its integration within the logging system might be envisioned, depending on the additional processing load it would induce.

4 Implementation of the measures of object exchange

This section describes how the qualitative and quantitative measurements identified in D2.20 will be effectively measured within the two scenarios. Any potential difference between the Human-Human and the Human-Robot observations are identified and justified.

To illustrate the different variables mentioned in this section, we use a data set from a preliminary study to overview relevant measures. In this data set, five pairs of participants exchanged an object across a 70 cm x 70 cm table. The object was the sensorised object described under section 3.2 to measure the grip forces and interaction force of the partners. 12 Oqus motion-tracking system (Qualisys, Sweden) camera tracked three light-weight spherical markers placed on the object surface to record the position and orientation of the object as well as the wrist positions of Passer and Receiver.

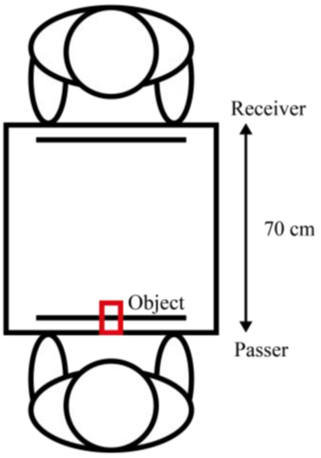

Figure 3. Workspace of the preliminary study viewed from the above. A line at each end of the table indicated a starting/final location.

The description of object exchange benefits from some definitions, and we used these definitions to assist characterising the preliminary data set. The two partners performing the task are referred as the Passer (that offers the object) and the Receiver (that accepts the object). The object thus is transferred from the Passer to the Receiver. In addition, we use the following workspace definitions:

- Longitudinal axis: the horizontal axis which joints the positions of the two partners in a straight line.
- Lateral axis: the horizontal axis perpendicular to the longitudinal axis
- Vertical axis: the remaining axis along the gravity

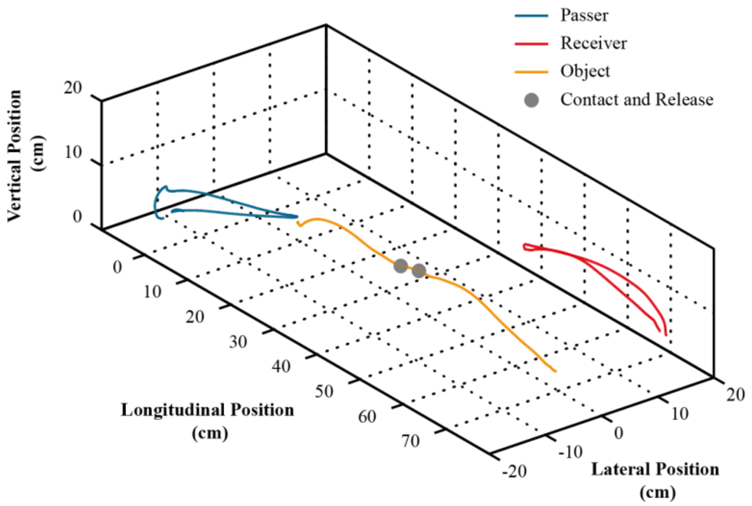

Figure 4: An exemplar movement of Passer, Receiver, and the object in the object exchange task. Note that the movements of the pair were measured at their wrists, thus displaced from the position of the object. Object contact and release positions are indicated

A single trial of object exchange can be divided into three continuous phrases (as it is illustrated on Figure 5). The first phrase is the *Approach*. We define the object lift-off by Passer as a start of Approach and the initial contact with Receiver as the end of Approach. The second phrase is *Contact*. This is the time between the initial contact and the moment at which Passer fully release his/her grip from the object. The third phase is *Completion* in which Receiver places an object to a target location.

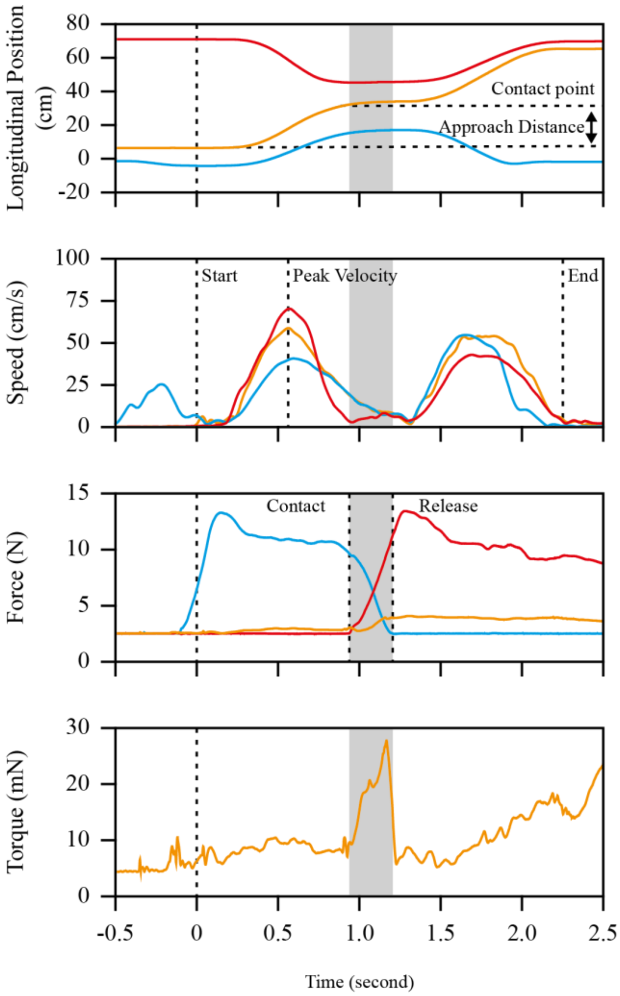

Figure 5: Movement profiles across time. Time is locked to the start of Passer and the shaded area indicates the period that the both partners were in contact with the object

4.1 Motion characterisation

4.1.1 Approach duration

The approach duration is the lapsed time between the onset of the movement by the Passer and the initial contact to an object by the Receiver. The former term is defined kinematically, such that the vertical movement of the object should be detected. The object transition can be very smooth in human-human case which makes kinematic detection of the first contact point challenging. Thus, at least for evaluation, we will use the force sensors in the sensorised object to define the first contact moment by the Receiver.

4.1.2 Arm motions

Several criteria are related to the motion of the partners' arms:

- Velocity profiles: The velocity profile tends to be bell-shaped in a simple arm movement, and this has been implemented in various models including the minim-jerk model (Flash & Hogan, 1985). The acceleration phase of the velocity profile is considered to reflect planned movements. On the other hand, the deceleration phase is modulated by online corrections of motor commands, and a use of on-line adjustments results in a longer deceleration period (Nagasaki, 1989, Plamondon, Alimi, Yergeau, & Leclerc, 1993)
- Acceleration and jerk profiles: To statistically demonstrate the change in smoothness of the trajectory, movement of the object Passer and Receiver will be quantified in terms of jerk metric (Rohrer et al., 2002). The jerk metric is calculated by taking the negative root mean

square of the jerk (rate of change of acceleration) normalised by the peak speed. Thus the higher the jerk metric, the smoother the trajectory is. Jerk metric is penalised by the peak velocity rather than movement duration as in RMS jerk (Hogan and Sternad, 2009), and therefore it is considered to be more sensitive to corrective movements, which is likely to be more relevant measure in CogLaboration.

During the Human-Human exchange observation, the motion of the arm will be observed using the motion capture system. In the Human-Robot experiments, we are expected to use the vision module to get an estimation of the human arm configuration. . Another option would be to use the portable motion capture system EasyTrack500 as well, but we still have to verify if this would affect the quality of the perception modules. The corresponding data regarding the arm will be obtained directly by logging the arm posture, which information provided by the arm controller.

In the Human-Human exchange, the contact position can be characterised as the wrist position at the instant of contact (provided by the object force sensors). In the case of trials performed with natural objects (i.e. not sensorised), the contact instant could be estimated and provided by a remote observer. In the case of Human-Robot experiments, the contact position can be estimated by the human arm pose estimated by the perception modules and the robotic arm configuration provided by the robot controller.

4.2 Object hand-over characterization

4.2.1 Transfer location

A pair of partners selects an arbitrary location in space to exchange the object. This position needs to reflect optimality in terms of ergonomics and sensory-motor control of the partners. For instance, the optimal object reception point may vary due to the physical limitation (too far to reach). Furthermore, spatial accuracy in the sensory-motor control is known to vary by locations in space (van Beers, Haggard, &Wolpert, 2004) or previous movement direction (Gordon, Ghilardi&Ghez, 1994), and its distribution is described in the shape of ellipse or ellipsoid. In our example data set, the partners meet the object at the mid-point while specific locations varied across pairs.

4.2.2 Contact velocity

Our data set showed that the velocity profile of Receiver appears more variable due to different styles of object exchange adopted by pairs. While some Receivers started the movement before Passer lifted an object, others waited for Passer before making movements. Furthermore, some Receiver reduced the velocity prior to contact while others maintained relatively velocity, highlighting two strategies of object exchange; one for receiving an object in slow-moving Receiver’s hand and the other for taking an object from a slow-moving Passer’s hand (see the illustration of this on Figure 6). A negative correlation of the contact velocity between Passer and Receiver ($r = -.69$) underlies effective interplay between the partners in selecting an exchange strategy.

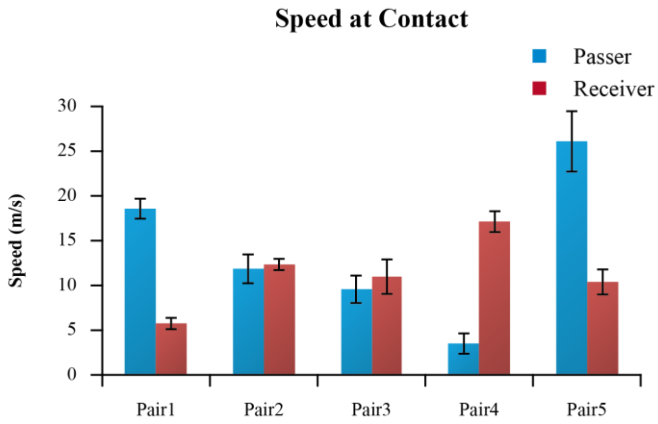

Figure 6: The speed of the pair at the moment of contact. Lower velocity indicates that the hand-over was conducted in a sequential manner. Error bars indicate one standard error

Similarly to the arm motion characterization, the speed at contact information is obtained during Human-Human observation through the motion capture system, while it is obtained for the Human-Robot observation using both the perception module and the robotic arm status information.

4.2.3 **Grasp position**

It has been shown that the way people grasp an object is affected by the physical characteristics of the object (Endo, Wing &Bracewell, 2011, Lederman & Wing, 2003). People can "automatically" plan a complimentary grasp consideration to an object currently held by another person (van Schie, Mars, Coles &Bekkering, 2004; Shibata, Suzuki, Gyoba, 2007). Contact point is evaluated largely in terms of qualitative measures in which we ask the subject how natural and effortless the object transaction was felt across a set of objects which are different in shape, size, and mass. We will also test the performance of the hand in terms of how the end-results are different from the intended grasp configuration due to the motion of the human user at around the contact period. For the purposes of the trials assessment this will be manually coded into a small set of descriptive parameters, e.g. natural vs unnatural, stable vs unstable, secure vs insecure. The actual descriptive pairs will be established during the early human-human trials on the basis of appropriateness.

In the Human-Robot interaction, the human evaluation of the exchange will be realized asking the subject feeling. The evaluation of the grasping configuration with respect to the intended position will be evaluated using the sensorised object. To do so, it is required that this object can be easily tracked by the vision module, which will be verified in the following months.

4.2.4 Contact period

Contact period is defined as the time between the initial contact moment by Receiver and the moment when Passer fully releases the grip from the object. This is illustrated on the force profiles in Figure 5. A short Contact Period is considered to be associated with a smooth transition of an object, but this assumption might need to be verified depending on the qualitative evaluation realised by the Human partner (s).

When using a sensorised object, the contact period can thus be defined through the analysis of the measured force variation. In the case of natural objects, we will indentify whether contact information provided by the robotic hand could be used to detect this instant, or eventually ask the partner(s) to verbally characterize these instants. . We will also investigate whether natural objects can be easily and simply equipped to enable the detection of such contact instant, taking into account any potential ethical and security issue. In the worst case, the contact information could be estimated by the operator or verbally identified by the Human partner realizing the exchange

4.2.5 Grip force modulation

For a successful manipulation of object, excessive grip force should be avoided because it fatigues the muscles and also it may break the object. The grip force of a human is reported to be scaled to the weight, inertia and the local friction of the object (Johanssonand Westling, 1984; Westling and Johansson, 1984). For a smooth transition between partners, a strong negative correlation in the grip forces by Passer and Receiver is expected, meaning that Passer reduces the grip force in time with the grip force increase by Receiver. Our exemplar data set showed the correlation coefficient of r = - .97 (± .02), indicating efficient communication of grip force control the pair.

This information will only be recorded and identified in experiments using the sensorised objects with embedded force and torque sensors.

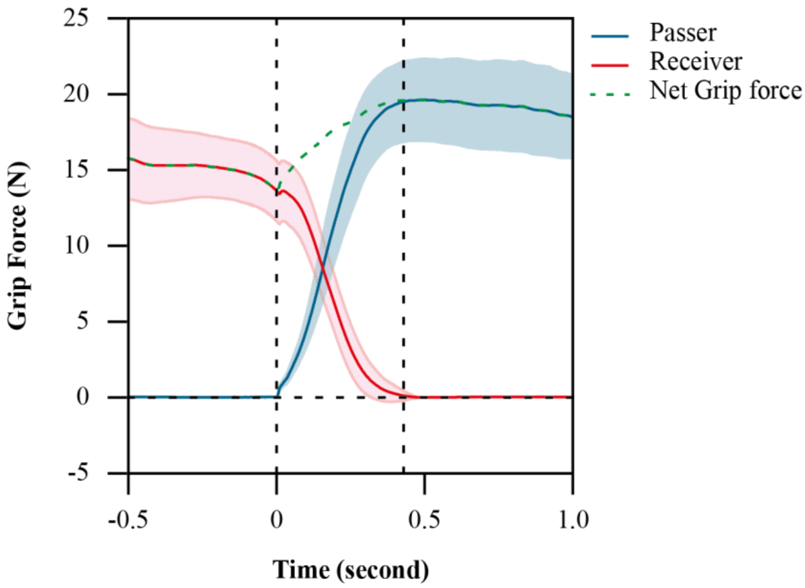

Figure 7: Average grip force modulations of five pairs duration contact. The shaded areas indicate one standard error.

4.2.6 Contact torque

As Figure 5 shows, the scalar torque is particularly sensitive to a contact between the pair. For smooth and practiced transition of an object, an excessive torque is expected to be avoided and the torque profile should be stereotypical (i.e. less cross-trial variability in the peak torque).

This information will be more extensively studied in the two scenarios mentioned using the sensorised object. In the human-Robot evaluation this information will be considered only for trials with this sensorised object.

4.3 Other measurements

4.3.1 Completion time

This is the time the Receiver spends to complete the task, counted from the moment the Passer releases the object. It is considered that the smooth transition of the object in an optimal fashion reduces the time required to complete the task.

In the experiment involving the sensorised object, this measure can be based on the force information measured by the object. In Human-Robot evaluation without the sensorised object, this information will be tracked using the grasping information provided by the robotic hand.

5 Quantitative Evaluation of Verbal/Gestural Recognition

Verbal and gestural recognition will be evaluated during the human-human trials to determine how successful they are in aiding the trials. However these will not be formally evaluated during the human-robot trails as they are simply an adjunct of the command system to provide information to the system. For gestural recognition, we will evaluate the command recognition in terms of frequency of pass or fail and completion time since the onset of the command. Psychophysics experiment where we can manipulate parameters?

5.1 Verbal recognition.

For verbal commands, the stability against user-dependent variability will be tested, including the pitch, volume, timbre, tone, accent, speed of the voice (maybe we will simulate voices with different attributes). We will also evaluate the reliability in the presence of background noises (TV, traffic, and other voices, echoes).

5.2 Gesture recognition.

The Human-Human observation will enable to identify a set of body gestures (through motion of the arm and/ or posture of the hand). The time necessary to recognize these gestures will be identified and compared with the time requested by the cognitive robot to realize the similar recognition.

6 Qualitative evaluation

The main qualitative measure used will be the Mean Opinion Score (MOS). This is essentially a guided subjective assessment of the quality of the transfer task. The central measure used is a rank, in this case from 1-5 However the problem with subject ranks is there comparability across subjects. One of the main problems here is that people are often unsure of the range of activity a scale is meant to measure. For instance if you ask someone to rate a meal they just had on a scale from 1-5 then some people will regard 5 as good while others will regard 5 as excellent. If people are given some guidance then you can expect quite different results if the guidance is that “5 means a perfectly acceptable meal” or that “5 means the best meal you have ever had in your life”, with the former producing higher mean scores. MOS attempts to give clear guidance, but to each point along the scale.

However, this is where another problem occurs, in attempting to provide guidance that has a meaning and relevance that can be similarly interpreted by the majority of people. MOS attempts to do this by first establishing a common vocabulary or terminology for the task being assessed. For Coglaboration this is done through establishing an extensive range of freeform answers to the question “How did the transfer task fell for you. Please be explicit” This is undertaken early on in the human-human trials with one person in the pair being the subject asked to respond and the other being an experimenter who is varying the quality of the transfer. Many trials are carried out with the same subject to establish a range of responses. Once these responses have been obtained from a large pool of subjects the responses are analysed looking for common words or phrases and the most common ones are then arranged along the scale 1-5 in ascending order of task quality. In the case where there are a number of words that are closely grouped, then a smaller set of trials is re-run, but this time the responses of the subjects is restricted to just those words in the candidate groups to find those that provide the maximum commonality and discrimination. Finally each point on the scale is given a descriptor based on the words or phrases that have highest agreement and discrimination. This guided scale is then used after each subsequent human-human and, particularly, human-robot trial to obtain a qualitative rating of the transfer task

Finally for a small number of trials a questionnaire of user satisfaction, happiness, safety, sense of ease and comfort will be administered after the trials to provide data on how acceptable the scenario was to the person but also as a check on the face validity of the MOS score.

7 Conclusions

This report has detailed a set of methods and procedures for evaluating the object passing task in Coglaboration. The evaluation centres on the actual passing task itself, rather than evaluating the performance of the individual sub-system components, although it is fairly obvious that these have to be working well in order to achieve a high quality and fluent passing behaviour.

The trials are split between human-human trials and human-robot trials, with each having a subset of scenario based activities designed to examine a wide range of passing manoeuvres and tasks. The human-human trials will primarily use motion capture data and sensors placed within or on the object being passed to gather the data for subsequent analysis. The human-robot trails will benefit from the additional data available from the robot subsystems, namely the robot arm, hand and vision system as a source of additional data.

The human-human trials are aimed at establishing the factors that determine a successful and fluent object passing task and consequently the results of these will modify, to a certain extent, the data that is collected, and the method by which it is collected, for the subsequent human-robot trials.

The proposed analysis is aimed at establishing objective measures of the main factors that could determine whether an object transfer task is deemed as natural (i.e. fluent and efficient) by the subject or not. For this reason a wide range of trajectory based analysis will be undertaken, backed up by analysis of grip patterns and force and torque data.

The quantitative data collection and analysis will be backed up by qualitative data. The primary method used will be a rating scale. This rating scale is a prompted rating scale designed to minimise subjective differences between different subject's evaluations. The main aim of this is to provide a subjective scale against which the quantitative data can be compared and normalised. The rating scale will be supplemted wityh a more open ended questionnaire to establish whether other factors may have affected the subject's attitude or performance during the trials.

These methods and procedures provide trhe baseline measures to be used in all the trials of the Coglaboration project and provide the means for comparison between trails. The methods and procedures presented here also provide the basis for assessing the performance of the Coglaboration system and, as such, provide a means for establishing the relative success of the project.

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