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# *Collaborative Robots' Perceived Safety CROPS*

## *Deliverable 1.2: Metrics for assessing perceived safety – observing the robot*

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# Contents

# 1 Introduction

Human perception of safety cannot be directly measured with some objective methods in contrast to robot detection of human and its proper safety response. In this document, we describe metrics used for assessing the perceived safety of humans while observing the moving robot at a distance. Metrics can be divided into three categories: self-report measures, physiological measures, and behavioural measures.

# 2 Self-report measures

Participants will be involved in self-report twice in the experiment. Firstly, before the experiment, filling demographic data and a personality test, and reporting initial acceptance of the robot. Secondly, participants will be asked about their perception of safety during the experiment.

## 2.1 Before the experiment

### 2.1.1 Demographic variables

The participants will report on their demographic characteristics, such as gender, age, level of education, employment status, and their profession.

### 2.1.2 The short version of the Big Five Inventory (BFI-K)

The BFI-K (Rammstedt & John, 2005) is a short version of the 44-item Big Five Inventory (BFI; John, Donahue, & Kentle, 1991) designed to assess the Big Five personality dimensions. It consists of 21 items rated on a 5-point Likert scale (1 – strongly disagree, 5 – strongly agree) and enables a quick assessment of the Big Five personality traits. The scales measuring extraversion (e.g., "I see myself as someone who is outgoing, sociable"), neuroticism (e.g., "… gets nervous easily"), agreeableness (e.g., "… is generally trusting"), and conscientiousness (e.g., "… does things efficiently") consist of four items, while the scale measuring openness comprises five items (e.g., "… values artistic, aesthetic experiences"). We will use the Slovenian version of the BFI-K (Zager Kocjan, 2016), which has comparable psychometric characteristics to the original version of the BFI-K.

### 2.1.3 Robot Acceptance Scale

We will use an adapted scale originally developed by Heerink et al. (2010), which has been used in many robot-related studies and was shown to have adequate psychometric properties (e.g., de Graaf and Ben Allouch, 2013; Di Nuovo et al., 2018). The scale is based on the Unified Theory of Acceptance and Use of Technology (UTAUT) developed by Venkatesh et al. (2003). It covers a wide range of technology acceptance components and is intended to be adapted to the specific requirements of the study at hand (e.g., measuring robot acceptance). The original version has 36 items that measure 13 different components (anxiety, perceived ease of use, perceived usefulness, etc.). For example, Latikka et al. (2019) used a modified version of the scale in which they retained one item from each of the nine chosen components.

For this study, the item review and selection procedure were done by four researchers from the Department of Psychology, University of Ljubljana. They chose and adapted seven items from seven components (one item per component).

Before participants start responding to the items from the Robot Acceptance Scale, they will be presented with a photo (Figure 1) of a robotic arm, used in our experiments, accompanied with the following description: "The figure below shows a modern robotic arm suitable for use in non-industrial environments. It can be used as an assistant in a home environment (e.g., help with cooking, cleaning, etc.) or work environment (e.g., help in laboratories, workshops, etc.). Such robotic arms have built-in mechanisms to ensure user safety. The robotic arm cannot injure the user with its movements or the tool it is holding."

*Figure 1: The photo of the Universal Robots robotic arm in the instruction part of the Robot acceptance scale.*

Robot Acceptance Scale consists of the following components (items):

- Anxiety ("When using such a robot at home or work, I would be afraid of doing harm by improper handling."),
- Attitudes towards technology ("Using such robots seems like a good idea to me."),
- Intention to use ("I would use such a robot at home or work."),
- Perceived Enjoyment ("I would feel comfortable using such a robot."),
- Perceived Ease of Use ("I do not think I would have a problem using such a robot."),
- Perceived usefulness ("Using such a robot would make it easier for me to work at home or work."), and
- Trust ("I would feel safe using such a robot.").

The items are rated on a 7-point Likert scale (1 – strongly disagree, 7 – strongly disagree).

We also added two simple Yes/No questions about previous experiences the participants had with such robot arms and with robots in general:

- Have you ever used such a robot arm at home or work?
- Have you ever used any kind of robot at home or work?
  - If yes, which robot(s) have you used? (open-ended question)

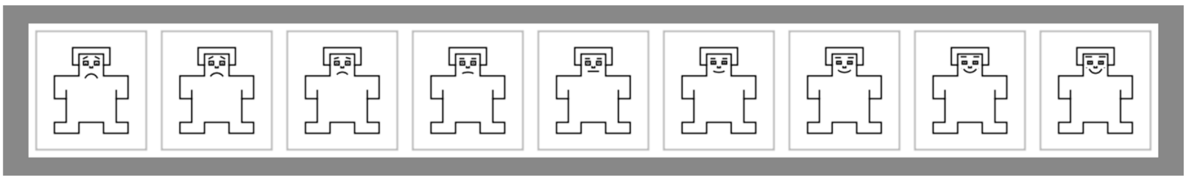
## 2.2 During the experiment

The questions that will be repeatedly administered during the experiment will be presented on a tablet computer. The application on the tablet consists of two questions assessing pleasure and arousal, two questions regarding perceived safety of the robotic arm and intention to collaborate with a robotic arm, and a simple computer game (driving simulator). In the first part of each experimental trial, the participant will simultaneously play the game and move towards the robot. The participants will thus have to divide their attention between the game (their gaze, not their full attention, will have to be fixed on the game) and the robot, which will still be present in their peripheral vision. This scenario will represent a simulation of a real work setting, in which the employees are collaborating with a robot (or just in its vicinity) and have to divide their attention between their task(s) and the robot/robot's task.

### 2.2.1 Self-Assessment Manikin scale

The Self-Assessment Manikin (SAM; Bradley and Lang, 1994) is a non-verbal pictorial assessment technique that measures pleasure, arousal, and dominance associated with a person's affective reaction to a wide variety of stimuli. We will use the first two items only (Figure 2) because dominance is not relevant to our study. We chose the version with nine pictograms. In our experiment, the participants will respond to different combinations of the robot arm movements and the tool the arm will be holding. Participants will need to choose the manikin that best represents their feeling when observing a robot.

Item: *Pleasure*



Item: *Arousal*

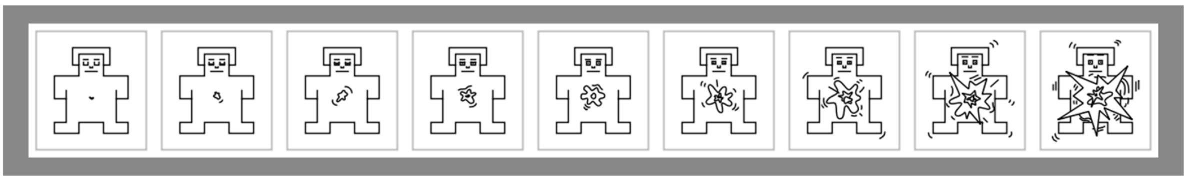


*Figure 2: The 9-point Self-Assessment Manikins for measuring pleasure and arousal.*

### 2.2.2 Perceived safety and intention to collaborate with the robot arm

During each trial/approach to the robot, the participants will respond on a 9-point Likert scale (1 – totally unsafe, 9 – totally safe) about their perceived safety of the robotic arm ("How safe did you find the robot movement?").

During each trial/approach to the robot, the participants will respond on a 9-point Likert scale (1 – not at all, 9 – most certainly) about their intention to collaborate with the robotic arm ("To what extent would you collaborate with a robot?").

# 3 Physiological measurements

The participants' physiological arousal will be measured with the BIOPAC sensory system comprised of an EDA sensor and PPG sensor described below. The measurement will start three minutes before the experiment and will last till the end of all trials. Data, captured with the BIOPAC logger, will be post-processed using the AcqKnowledge Research Biopac software.

EDA is a measurement of eccrine activity that is influenced by sympathetic nervous system activity, resulting from environmental stimuli. EDA increases with excitement, exemplified by the sweaty palms one may experience. Measuring EDA involves measuring skin conductance, which leads to measuring the nervousness of the participant. Measuring is done by placing two electrodes on the participants' fingers, and a low constant voltage is applied (not felt by the participant). Then the current flowing as a result of this applied voltage is measured and converted to conductance following Ohm's law. Skin conductance is measured in units of microsiemens, with average human EDA ranging from 1 to 20 microsiemens.

PPG is an optical sensor that is used to detect blood volume changes in the microvascular bed of tissue, which leads back to the heart rate of the participant. The change in volume caused by the pressure pulse is detected by illuminating the skin with the light from a light-emitting diode (LED) and then measuring the amount of light either transmitted or reflected to a photodiode.

# 4 Behavioural measurements

The distances from the participant to the robotic arm in each trial will be measured with NanoScan3 safety laser scanner by SICK. The safety laser scanner operates on the principle of time-of-flight measurement. It emits light pulses in very short regular intervals. When the light strikes an object, the light gets reflected. The safety laser scanner receives the reflected light and calculates the distance to the object based on the time interval between the moment of transmission and moment of receipt.

At the beginning of each trial, the participants will be asked to start playing the driving simulation game (participants need to divide their attention between the robot and the computer game) and move towards the robot to a point (i.e., the distance to the robot) where they still feel safe, which will represent the participant's comfort zone 1. Afterwards, they will be allowed to place their full attention on the robotic arm and asked to either (a) move closer to the robot, (b) stay in their current position, or (c) move further from the robot, depending on their perception of safety. The resulting distance to the robot will represent the participants' comfort zone 2 when participants will be fully attentive to the robot movement.

## 4.1 Task: a simple driving simulation computer game

Participants will play a simple android game that was developed within the Unity environment. The aim of the game is to steer the car along a curved road (Figure 3). It will be played on the 10.4" android tablet. The car has a constant forward speed. The steering is implemented by tilting the tablet sideways: tilt to the left will move the car to the left and vice-versa. The movement is assessed by the inertial measurement unit integrated into the tablet. The participant must keep the car as close to the centre of the road as possible. While playing the game, the deviation from the middle of the road is calculated and saved.

Along the road are set empty objects with their coordinate system in the centre of the road. During driving, the collision point between the centre of the car and the empty object is checked continuously. The deviation is specified as the distance between the centre of the empty object and collision point. The road is pre-drawn in the length of 2 m, but the road goes to infinity by stacking the 2 m sections. All subsequent sections of the road are randomly rotated around the X or Y-axis. With this rotation, the newly generated road does not have the same curves as the previous ones.

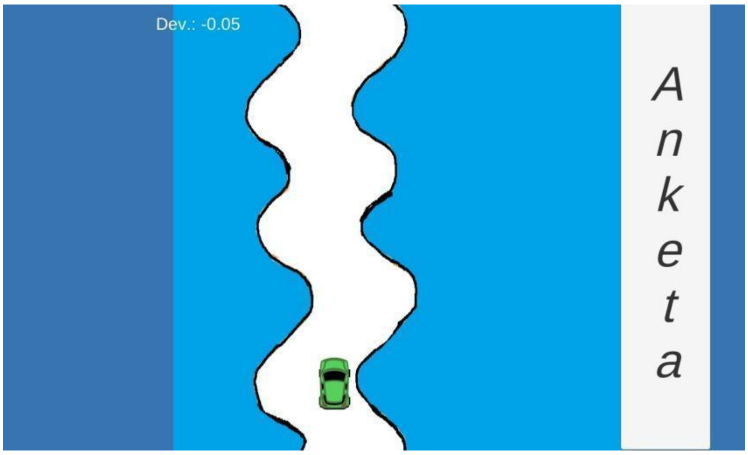



*Figure 3: A simple driving simulation game used in the first part of the approach towards the robot arm.*

# 5 After the experiment

## 5.1 Debriefing

After the experiment, a short debriefing will be performed with each participant. Participants will be asked about other feelings and perceptions they could not express during the experiment. This data can help us plan future experiments and provide additional insights into the perceived safety of the robotic arm.

# 6 Experimental design of Experiment 1

In Experiment 1, we will examine the influence of three independent variables on the selected self-reported, behavioural and physiological measures:

- type of tool (2 levels): safe (sponge for wiping the board), dangerous (kitchen knife);
- robot speed (2 levels): slow (0.3 m/s), fast (1 m/s);
- type of robot movement (6 levels): *linear* forward/backwards, *linear* left/right, *linear* up/down, *circular* left/right, *circular up/down* and random movements (which presents a combination of the other five movements).

With such a research plan, we obtain 24 (2 x 2 x 6) experimental conditions. Every participant will be exposed to each of the conditions only once, and the order of the conditions within each participant will be randomized.

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