Measuring Habituation during Human-Robot Interaction

Grigorios D. Skaltsas

Abstract— **Using measurements of physiological signals (eye-tracking, galvanic skin response, heart rate) and questionnaires during a series of human-robot interaction experiments, user stress metrics and habituation patterns are analyzed. The initial experimental results indicate that there seems to be a varying relation between human stress and robot speed as the human gets acquainted with the robot which seems to be also affected by the human perception of the task's success.**

I. INTRODUCTION

SECURE project is related to the security during the interaction between a human and a robot. Furthermore, the advertised position in the University of Hertfordshire was related to social robotics. Further to basic industrial safety standards, the psychological perception of safety seems to be a topic that many researchers are investigating from a variety of different approaches. However, proxemics and physiological sensing studies seem to dominate the psychological robot safety research domain [1].

Reading and evaluating the human's adaptation through biological signals could be the base for a performance optimization system targeting the minimization of human stress during the interaction [2-4]. It has been shown that safety is still perceived as low when the robot's trajectory planning and execution seems to be only avoiding collision [1]. Therefore, safety design has to include psychological factors which could be the adjustment of various parameters of the robot's motion, such as the speed profile in terms of acceleration, deceleration, maximum and minimum speed, proximity to the human or other objects, and also adjustments of behaviour based on robot's appearance [1].

Cultural and personal preferences identify which everyday human interaction characteristics are also important to implement in human-robot interaction (HRI). Methods employed, are commonly questionnaires, physiological metrics, and behavioural metrics [5].

The notion of studying the user's habituation after a number of trials and identifying personal or generic trends in short or long term seems to not have been performed even in recent publications. The reason the habituation is studied in this project is so that more systems that adapt to the human as the human adapts to them. Then the robots can gradually increase their performance without being stressful to the humans whereas if the human has to adapt to an unknown system might result in low acceptance of the system or a rejection altogether especially if there is no prior knowledge about it.

For the research purposes, one study was carried out and two are yet to be completed where primarily galvanic skin response (GSR), heart rate (HR) and eye-tracking (ET) are analysed during sessions where the human is mostly passive whilst the robot is active.

II. RELATED WORK

The following section shows some of the most related work sorted by data acquisition method. Some of the related studies combine more than one method. However, they are presented in the correspondent sections bellow based on the importance of the method used in the study and the critical points that highlight the usefulness of the method.

A. *Galvanic Skin Response*

GSR consists in reading the changes in human skin's conductivity when the sweat micro-glands respond to stressful situations. Dehais [6] used a motion planner based on Sisbot [7] for planning. A robot approached the human and handed an item. A training trial was performed with the users before the actual experiment, therefore the measured signals had already some adaptation effect. Kulic and Kroft used a predefined algorithm on a robotic manipulator that was fixed and the user was also sitting on a chair at a safe distance without being required to intervene to the task [8]. In their study it was demonstrated that by using a fuzzy interference controller, the user stress levels could be minimized in subsequent trials.

B. *Eye-Tracking*

ET offers physiological and subjective evaluation by correlating ET data with questionnaire responses

---

*Research supported by SECURE project https://secure-robots.eu. funded by the EU Horizon 2020 research and innovation programme under grant agreement No 642667 (SECURE)

[6]. Overall in Human-Computer Interaction (HCI) as well as HRI, eye-tracking has been used to provide vision analytics [9] and offer an additional modality [10].

C. Heart Rate

Heart-rate in HRI has been used as a primary physiological response measure [11]. In another study two systems, one wearable and one laboratory high precision sensor were used to evaluate the user's response to some pictures shown and by immediately then filling a brief questionnaire [12]. Although in both experiments the HR measurements yielded measurable consistent results, it was not discussed how any possible habituation effects might in long term affect the measurements.

D. Questionnaires

Questionnaires have been widely used in HRI [13-15] as a method to collect user's feedback.

Joosse et al developed the BEHAVE II questionnaire that separates the responses based on attitude and behavior [16]. Morales et al tried to evaluate pleasantness of motion planning of an autonomous wheelchair via questionnaires [17].

[6] has combined physiological responses with questionnaires in an attempt to combine each other's results so that physiological responses will match the user's post experiment evaluation.

RoSAS questionnaire demonstrated that robot's appearance impacts its social evaluation [18].

Ragot et al performed a study where the participants had 15 seconds after every scene projected on a screen to self-assess in a 2 dimensional scale their arousal and valence [12]. The difference between this and previous studies is that the questionnaire was completed in small portions using simple numeric scales after each event so that the users could reflect more easily on how they felt and provide the "ground truth" tags for the recorded physiological data.

III. APPROACH

The objectives of the first experiment are to:

- Compare the findings of previous experiments in related studies verifying that the results are similar [6, 19, 20].
- Provide actual data on HRI sessions, where the human is passively participating, both from questionnaires and sensor readings.
- Explore the habituation patterns that might appear, create the proposed statistical model as a correlation between the sensor readings and the replies on the questionnaires.

A. Design of the Experiment

The experiment explored short-term habituation and had participants mostly being students and local residents from the nearby area that can access the university easily. The sample contained 29 participants (Male: 22, (Age: 34.5avg 10.7std) Female: 5 (28avg 4.9std)). Their knowledge on digital equipment was marked high on the average. The participants were split in four groups. All groups had to experience four distinct sessions.

For the habituation effects' study, all the sessions run sequentially with a small pause in between for a few minutes until the questionnaires are completed. The users had to evaluate their experience with the robot, combining it with the overall effectiveness of the task, whilst their physiological responses were recorded.

After the participants entered the lab, they read the participant information sheet and signed the consent form, the sensors were then fitted, calibrated and tested on each user on an individual basis at the beginning of the experiment. In order to obtain a base line for the GSR, a small resting period was introduced. The ET sensor had to be calibrated on an individual basis. In order to keep the base GSR updated, small pauses of a minute were introduced between the completion of the questionnaire and the next session.

In each session, the robot approached them from a distance of approximately 5 meters after coming out of an initial location where it would not be visible to the user. The robot during each session acted in a fully autonomous way, acting totally independent of any of the user's sensor measured feedback.

The structure of the sessions was based on the combination of two conditions. The first condition was the robot's speed and hence the perceived risk by the human of the robot crashing onto a wall or on the human upon approach. The speed choices were based on the robot's capabilities. The second was the delivery of an item that was on the robot but not securely attached to it, hence an extra risk perceived by the human as task failure, such as dropping the item at some point or seeing the item shaking during the transportation. For this experiment, the item chosen was a half full semitransparent water bottle. The user could see the shake of the water during its transportation by the robot. The combinations of these conditions create the following session scenarios:

- Fast speed carrying the bottle

- Slow speed carrying the bottle
- Fast speed without carrying the bottle
- Slow speed without carrying the bottle

To avoid bias, users were grouped as described earlier and set to participate in possible combinations of sequences of session scenarios as shown on table 1. The first two sessions for each group consist of the robot varying its speed alone. The last two sessions add the bottle carrying task combined with the variations of the speed. Adding the extra risk at the last two sessions of the experiment, compensates for the user's loss of interest and changing one condition each time helps compare the changes in the habituation pattern of each group in a controlled manner. The table, for clarity, is coded as follows:

- Condition: Fast (F), Slow (S)
- Carrying a bottle, Yes (B), No ( )

TABLE I. Table of User Groups

Group	session			
	1	**2**	**3**	**4**
1	F	S	F+B	S+B
2	F	S	S+B	F+B
3	S	F	F+B	S+B
4	S	F	S+B	F+B

Cumulative Robot's Speed and Task Pattern over each session.

The robot did not communicate to the user its movement intentions in any session. The users experienced the robot planning its movement spontaneously from by their visual perception of the robot's location and the engine's noise.

B. Platform and Sensory Choices

University of Hertfordshire's custom platform "sunflower", a service robot comprising of a mobile base, a waist link, and a tray. It is a medium sized robot built on a Pioneer 3DX base using two wheels on each side for its navigation. It has a static head, with non-functional large round 'eyes', mounted on a dynamixel based chain neck with 4DOF [21]. GSR and HR [22] and eye-tracker sensors were used for the physiological measurements [23].

C. Robot Trajectories and Speed Choices

The path of the robot (figure 1) was chosen so it would have maximum visual exposure to the user.

Also, it was combined with a maneuver that requires a sharp turn (top right corner) and the potential of a crash upon failure when it was still away from the user. The duration of the slow trajectory is approximately 48 seconds and 20 seconds for the fast one, giving enough time to the user's GSR to rise and drop approximately at the time when an event causing stress occurs. The user's curiosity should be heightened as to why the robot chooses this path to follow as opposed to a direct approach. The user should perceive the robot not as a completely human-like thinking entity but as a system with some way of reasoning that does not necessary act the way a human would. This, sebsequently, was revealed by the discussion with some of the participants and their questionnaire responses. It appears that it had an impact on the assessment of the task's efficiency later on in the questionnaire's section.

The speed is approximately 0.7 Km/hour in the fast mode and 0.47 Km/hour in the slow mode. In both fast and slow trajectories, the robot covers approximately 3.1 meters in the first straight segment and 5.75 meters in the second in which it approaches the participant. The turning lasts 3 seconds and including the stop and start of the robot on the turning spot is approximately 6 seconds. The safety distance is 30 to 50 cm from the participants' feet.

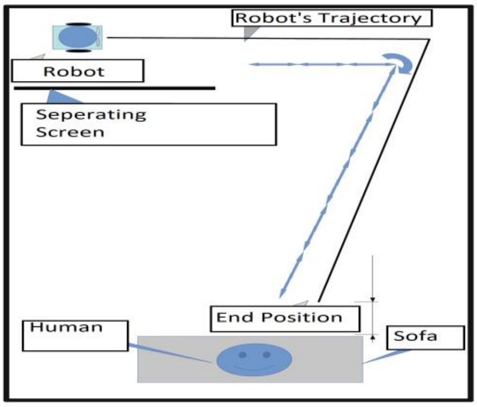

Figure 1 (Top View of Robot's Trajectory during each session)

D. Questionnaires

There are four questionnaires used for this experiment.

Once the first trial ended, the (1) "demographics sheet" asking age, gender, expertise with computers among others, the (2) "behind the wall" asking about the users experience whilst the robot was not visible and one copy of the (3) "main questionnaire" was handed out to the user whilst the sensors were still fitted.

The (3) "main questionnaire" was handed to the user after each trial. Hence it was completed four times for each user. It asked the user to evaluate the robot's performance. It also required the user to indicate on a schematic showing the robot’s trajectory during the trial, the parts where the robot was too fast or slow as well as where it could have failed the task. The (4) “general questionnaire” -which is handed out in the end- asking the user about his/her overall experience, as well as the (4) “demographics sheet” have the purpose to normalise the responses of the user.

IV. PRIMARY RESULTS AND POINTS TO BE ADDRESSED

Results are under analysis. From a qualitative point of view, there seem to be repeated patterns for most users’ physiological responses in relation to specific events. User perception of the task’s risks and complexity varies seemingly as the conditions vary in ways that the physiological responses do not always correspond to the questionnaire responses.

Emerging features such as stress signs due to specific event anticipation and their variance are currently being studied. For example, once the user has experienced the robot’s trajectory for the first time, how long it takes before the turning point is reached and hence his/her GSR peaks anticipating the potential crash on the wall. Furthermore, how this changes when the speed changes or the task of carrying the bottle.

V. FUTURE WORK

There are two more experiments to be carried out. Their aim is to provide results that will clarify some points from the first experiment.

The second experiment is focused on a simpler unique movement with more repetitions in a higher speed. The third experiment will be focused on the user hearing the robot approaching. Study of stress and habituation of events such as low intensity touches of the robot to the seat are also under consideration.

The results of all the experiments’ data might help drawing further conclusions on human stress and habituation during HRI and suggest methods of minimizing stress.

REFERENCES

[1] P. A. Lasota, T. Fong, J. A. Shah, and others, "A survey of methods for safe human-robot interaction," *Foundations and Trends in Robotics*, vol. 5, no. 4, pp. 261-349, 2017.

[2] R. R. Fletcher, K. i. Amemori, M. Goodwin, and A. M. Graybiel, "Wearable wireless sensor platform for studying autonomic activity and social behavior in non-human primates," in *Proc. Annual Int. Conf. of the IEEE Engineering in Medicine and Biology Society*, 2012, pp. 4046-4049.

[3] I. Daly *et al.*, "Towards human-computer music interaction: Evaluation of an affectively-driven music generator via galvanic skin response measures," in *Proc. 7th Computer Science and Electronic Engineering Conf. (CEEC)*, 2015, pp. 87-92.

[4] A. Sano and R. W. Picard, "Stress Recognition Using Wearable Sensors and Mobile Phones," in *Proc. Humaine Association Conf. Affective Computing and Intelligent Interaction*, 2013, pp. 671-676.

[5] G. Castellano, I. Leite, A. Pereira, C. Martinho, A. Paiva, and P. W. McOwan, "Detecting Engagement in HRI: An Exploration of Social and Task-Based Context," in *Proc. Risk and Trust and 2012 Int 2012 Int. Conf. Privacy, Security Conferece Social Computing*, 2012, pp. 421-428.

[6] F. Dehais, E. A. Sisbot, R. Alami, and M. Causse, "Physiological and subjective evaluation of a human-robot object hand-over task," *Applied ergonomics*, vol. 42, no. 6, pp. 785-791, 2011.

[7] E. A. Sisbot, L. F. Marin-Urias, X. Broquère, D. Sidobre, and R. Alami, "Synthesizing Robot Motions Adapted to Human Presence," *International Journal of Social Robotics*, vol. 2, no. 3, p. 329, September 2010.

[8] D. Kulic and E. Croft, "Physiological and subjective responses to articulated robot motion," *Robotica*, vol. 25, no. 1, pp. 13-27, 2007.

[9] K. Kurzhals, M. Hlawatsch, C. Seeger, and D. Weiskopf, "Visual Analytics for Mobile Eye Tracking," vol. PP, no. 99, p. 1, 2016.

[10] P. Kasprowski, K. Harezlak, and M. Niezabitowski, "Eye movement tracking as a new promising modality for human computer interaction," in *Proc. 17th Int. Carpathian Control Conf. (ICCC)*, 2016, pp. 314-318.

[11] B. Kuehnlenz and K. Kuehnlenz, "Reduction of Heart Rate by Robot Trajectory Profiles in Cooperative HRI," in *Proc. ISR 2016: 47st Int. Symp. Robotics*, 2016, pp. 1-6.

[12] M. Ragot, N. Martin, S. Em, N. Pallamin, and J.-M. Diverrez, "Emotion Recognition Using Physiological Signals: Laboratory vs. Wearable Sensors," presented at the International Conference on Applied Human Factors and Ergonomics, 2017.

[13] A. Chanseau, K. Dautenhahn, K. L. Koay, and M. Salem, "Who is in charge? Sense of control and robot anxiety in Human-Robot Interaction," in *Proc. 25th IEEE Int. Symp. Robot and Human Interactive Communication (RO-MAN)*, 2016, pp. 743-748.

[14] K. L. Koay, K. Dautenhahn, S. Woods, and M. L. Walters, "Empirical results from using a comfort level device in human-robot interaction studies," in *Proceedings of the 1st ACM SIGCHI/SIGART conference on Human-robot interaction*, 2006, pp. 194-201.

[15] M. L. Walters, M. A. Oskoei, D. S. Syrdal, and K. Dautenhahn, "A long-term Human-Robot Proxemic study," in *2011 RO-MAN*, 2011, pp. 137-142.

[16] M. Joosse, A. Sardar, M. Lohse, and V. Evers, "BEHAVE-II: The revised set of measures to assess users’ attitudinal and behavioral responses to a social robot," *International journal of social robotics*, vol. 5, no. 3, pp. 379-388, 2013.

[17] Y. Morales, A. Watanabe, F. Ferreri, J. Even, K. Shinozawa, and N. Hagita, "Passenger discomfort map for autonomous navigation in a robotic wheelchair," *Robotics and Autonomous Systems*, vol. 103, pp. 13 - 26, 2018.

[18] C. M. Carpinella, A. B. Wyman, M. A. Perez, and S. J. Stroessner, "The Robotic Social Attributes Scale (RoSAS): Development and Validation," in *Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction*, Vienna, Austria, 2017, pp. 254-262: ACM.

[19] T. Arai, R. Kato, and M. Fujita, "Assessment of operator stress induced by robot collaboration in assembly," *CIRP annals*, vol. 59, no. 1, pp. 5-8, 2010.

[20] D. Kulic and E. Croft, "Anxiety detection during human-robot interaction," presented at the Intelligent Robots and Systems, 2005.(IROS 2005). 2005 IEEE/RSJ International Conference on, 2005.

[21] lirec.eu. Available: http://lirec.eu/project

[22] shimmersensing.com. Available: https://www.shimmersensing.com/products/consensys-ecg-development-kits-update

[23] imotions.com. Available: https://imotions.com/asl-eye-tracking-glasses/