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CoLLaboratE

Co-production CeLL performing Human-Robot Collaborative AssEmbly

D2.7 – Behavioral Experiments to Demystify and Improve Key Human Factor Aspects of HRC (preliminary)

Due date: M18

Abstract:

The present document presents the work that has been done for the T2.4: Behavioral Experiments to Demystify and Improve Key Human Factor Aspects of HRC. It is part of the framework design, requirements & social studies feedback. The report includes the findings of a literature review that was conducted to identify the state-of-the-art behavioural interventions that can be used in the use cases with the purpose to facilitate Human-Robot Collaboration (HRC). Furthermore, it includes the design and results of a preliminary study which was performed to test a potential behavioral intervention, as well as the design of a confirmatory study (soon to be conducted) of the results of the preliminary study.

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PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
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EXECUTIVE SUMMARY

A successful implementation of industrial HRC can enhance quality and the resilience of the manufacturing, increase production output and last but not least reduce product cost. The main goal of the T2.4 (which is related to this deliverable) is to apply state-of-the-art behavioral interventions to facilitate the successful HRC in the use cases.

A very important element of a successful HRC is the human trust towards robots. Humans must trust that the robot protect the interests and welfare of all the human members of the HRC team. Trust is crucial in developing an effective human-machine interaction. The level of trust human put on any robotic partner it is very critical, especially in high-risk situations.

One of the most popular ways to facilitate HRC that has been used by studies is anthropomorphism. Anthropomorphism is an inductive process, where nonhuman agents get attributed distinctive human characteristics, such as conscious feeling.

Findings of previous studies show that anthropomorphism can be used to stimulate robot trust and facilitate a successful HRC [1] [2]. Therefore, we decided to use anthropomorphism to try to facilitate HRC in the use cases of CoLLaboratE. To ensure the success of our interventions we decided to pre-test some of most suitable of them for the use case. To test the techniques we designed laboratory studies in which we will implement the techniques and assess their impact on human trust and the acceptance towards robots.

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Abbreviations and Acronyms

Partner's short name	Partner's full name
AUTH	ARISTOTLE UNIVERSITY OF THESSALONIKI
CERTH	CENTRE OF RESEARCH AND TECHNOLOGY HELLAS
ARMINES	ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPMENT DES METHODES ET PROCESSUS INDUSTRIELS
JSI	INSTITUT JOZEF STEFAN
IDIAP	FONDATION DE L'INSTITUT DE RECHERCHE
UNIGE	UNIVERSITA DEGLI STUDI DI GENOVA
KU Leuven	KATHOLIEKE UNIVERSITEIT LEUVEN
LMS	UNIVERSITY OF PATRAS
CRF	CENTRO RICERCHE FIAT SOCIETA CONSORILE PER AZIONI
BOR	BLUE OCEAN ROBOTICS
ASTI	AUTOMATISMOS Y SISTEMAS DE TRANSPORTE INTERNO SA
KOL	KOLEKTOR ORODJARNA NACRTOVANJE IN IZDELAVA ORODIJ TER ORODJARSKE STORITVE D.O.O.S
ARCELIK	ARCELIK A.S.
ROMAERO	ROMAERO S.A.

Abbreviation	Definition
WP	Work Package
D	Deliverable
EC	European Commission
EU	European Union
HRC	Human-Robot Collaboration

1 INTRODUCTION

The main goal of T2.4 is to identify and apply behavioral intervention to facilitate the HRC in the uses cases. A behavioral intervention is any planned action which targets to alter the psychology and/or behavior of people towards a given direction, in the case of T2.4 towards the facilitation of HRC. To be able to do this the appropriate intervention should be identified. Therefore, an extensive literature review was conducted to map the potential behavioral interventions. The literature review examined the state-of-the-art insights about the interaction of human and robot as well as other technologically advanced non-human agents (e.g. avatars) and identified prominent and promising areas of intervention.

The results of literature review were used as a guide to pick some intervention that deemed to be suitable for the robots of the use-cases. However, before implementing them, the notion of the interventions had to be tested in laboratory studies in highly controlled conditions to assess the degree of suitability of the intervention. Therefore, a set of studies were designed to test the interventions. A small preliminary study was conducted in May 2019. The results provided a first insight into the potential of a possible intervention. Furthermore, two more large-scale studies have been planned for the first semester of 2020.

2 LITERATURE REVIEW

2.1 HRC AND TRUST

According to the International Organisation for Standardisation [3] HRC is a "special kind of operation between a person and a robot sharing a common workspace". A successful implementation of industrial HRC can enhance quality and the resilience of the manufacturing, increase production output and last but not least reduce product cost [4]. Until recently, a very close collaboration between industrial robots and human workers has traditionally been stalled largely due to safety concerns. Companies were trying to mitigate accidents which cause injury to the human operator. Recent technological advancements, however, have dramatically increased the potential of HRC as collaborative robots which started to become more lightweight, compact and designed with human safety as a priority [5]. What is more, health and safety regulations are also being advanced to reflect the advancements in robot's design which in turn allow some closer cooperation between the robots and the operators [3]. Thus, HRC is expected to greatly increase in the near future.

For a human-robot team to accomplish its goals and be successful, humans must trust that the robotic member of the team will protect the interests and welfare of all the individuals on the team. Trust is "the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability" [6] and thus, it is crucial in developing an effective human-machine interaction. The level of trust human put on any robotic partner is very critical, especially in high-risk situations [7]. Trust is particularly important in these high-risk contexts as it directly affects peoples' willingness to accept information coming from the robot, follow robots' suggestions, and as a result benefit from the advantages robotic systems can provide [8]. Trust therefore can greatly affect the decisions that humans will make in uncertain or risky environments (when it comes to HRC) [9]. For example, the less trust an individual places on a robot, the sooner he or she will intervene as a task progresses toward its completion and this might potentially compromise the success of the task [10].

Although people might interact daily with machines that both appear and behave like humans, trust between a human and a machine is unique and it often varies in initial perceptions, monitoring behaviors and judgments [6]. In human-automation interaction, a unique phenomenon known as "automation bias" takes place and causes people to ascribe higher authority, greater expected performance and higher initial trust to machine-like agents [11] than human agents [12]. Despite the fact that human agents gather initial higher liking, bias for trusting a machine-like automation seem to persist [11] [12]. Nevertheless, this initial trust to machine-like agents can quickly collapse once a machine appear to be less consistent and perfect as expected and fail to meet people's high expectations [13]. These results indicate that in cases of extremely high levels of trust, people tend to rely excessively on technological agents, whereas in cases of low levels of trust, people tend to disuse technological agents [6] [12].

Literature findings show that trust is an important element in a successful HRC. Therefore, trying to increase the levels of trust humans place on robots is of utmost importance to facilitate HRC in the use cases.

2.2 Anthropomorphism and HRC

One of the most popular ways to facilitate HRC that has been used by studies is anthropomorphism. Anthropomorphism is an inductive process, whereby distinctive human characteristics, such as conscious feeling, are being attributed to nonhuman agents [14]. The very essence of anthropomorphism seem to lie at the attribution of humanlike characteristics, motivations, intentions and emotions to imagined or real behavior of nonhuman agents [15].

Nevertheless, anthropomorphism goes beyond attributing superficial human characteristics (like humanlike face or body) to attributing essential human characteristics to the nonhuman agent, such as a humanlike mind, capable of generating thoughts and emotions [14]. As the "theory of the mind" assumes, people tend to attribute a "mind" to other human beings in order to explain the behavior of any independently acting agent and predict its behavior [16]. Thus, the presence of humanlike mental state, such as intention, emotion, cognition, is the defining feature that distinguishes humans from other agents [14]. Several theories of humanness confirm that humanness is being interpreted in terms of emotion that implicates higher order mental process [17] and traits that involve cognition and emotion [18].

In order to explicate people's need to anthropomorphize, scholars tried to determine the psychological factors that cause people to use anthropomorphic explanations of nonhuman agent's behavior. Research suggests that people are more likely to anthropomorphize when anthropocentric knowledge is accessible and applicable, when motivated to be effective social agents and when lacking a sense of social connection to other humans [15]. Human desire for social connection and their need to explain, to predict and consequently to control other agents are the two fundamental motivations that trigger anthropomorphism [16].

Anthropomorphism is a critical parameter not only in understanding human-computer interactions, but also for improving the usefulness of certain technological agents [15]. Although external appearance is crucial to the way humans perceive other objects anthropomorphism is more of a process of inference about unobservable characteristics of the nonhuman agent, rather than descriptive reports of a nonhuman agent's observable behavior [15]. For example, by building nonhuman agents with the necessary features that will allow them to perceive the world as humans (e.g. using two cameras as eyes), engineers might achieve human - computer interaction in the same way as humans interact with each other [19].

But the most important issue regarding anthropomorphism (see nonhumans as human) remains whether people will accept nonhuman agents and treat them with respect as moral agents or merely as objects. Nonhuman agents that have humanlike mental capacities are presumed to have the ability of autonomous self-directed behavior and therefore, its actions can be considered as intentional. Human-like robots that both appear and behave like humans are treated less harshly than machine-like robots [20], due to the fact that people can more easily relate and empathize with them [21]. Increased familiarity with an agent can decrease feelings of unease towards a technological agent's appearance [22]and thus, interaction may be the key to enhance anthropomorphism and alleviate unnerving feelings towards robots.

2.3 Anthropomorphism and Trust on Robots

Humanlike appearance and behavior of technological agents are the most important features that can affect trust to nonhuman agents and thus, by adding these anthropomorphic features, engineers can indeed increase trust [2] [12]. Robot voice and eye gaze are some influential human features in human-robot social interaction. Service robot's voice pinch can create positive feeling towards humans and thus, robots with a higher pinched voice are perceived as more attractive and pleasant [1]. Anthropomorphized vehicles with human features like voice and gender, are considered to be more trustworthy and even in case of an accident, people were more relaxed and couldn't blame their vehicle for an accident caused by another driver [2].

Stanton & Stevens [23]reported an unpredicted effect of the eye gaze on human-robot interaction. On the one hand, robot gaze can improve human performance on easy trials due to performance anxiety experienced during difficult trials, but on the other hand, robot gaze has a significant positive impact upon human's compliance and trust on difficult trials. Moreover, an experimental study in humanoid robots displaying gaze turn-taking cues revealed not only the positive affect of perceived anthropomorphism on trust, but also the moderating role of the level of human-robot interaction comfort on perceived anthropomorphism [24]. People that feel comfortable interacting with robots, experience positive emotions that cause them to process interaction cues less carefully and pay attention only to superficial features, such as appearance, than those experiencing negative emotions of discomfort [25]. Therefore, humans that feel comfortable interacting with robots tend to anthropomorphize robots with human-like appearance, whereas humans that feel less comfortable interacting with robots tend to anthropomorphize robots with human-like social functioning features [24]. These results imply that it depends on the desired interaction outcome whether engineers will enhance specific anthropomorphic features, such as social functioning or appearance, in order to achieve higher levels of acceptance and trust.

The results of the aforementioned studies show that anthropomorphism can indeed be used to induce more trust in a human-robot interaction.

2.4 Uncanny Valley

Although anthropomorphism is a quite effective as technique to make robots more likable and as a result to create trust has some pitfalls. Mori [26] formulated the uncanny valley theory to describe the emotional reaction towards anthropomorphic robots. As it can be depicted in Fig. 1, as the human likeness of a non-human agent increases, people's emotional response to the stimulus becomes more positive. However, as human likeness reaches near perfection, people's emotional response starts declining and can become strongly negative. The region which immediately follows the start of the decline is the uncanny valley. Consequently, the uncanny valley theory assumes that negative emotions can be the result of a non-humans agent's placement on a continuum of human likeness. Researchers have proposed a variety of reasons to explain phenomenon (e.g the fact that some human replicas elicit the uncanny feeling), including social, cognitive, evolutionary and psychodynamic approaches [27]. The fact remains that anthropomorphism can sometimes backfire and lead to the opposite results when it comes to robot likeness and trust.

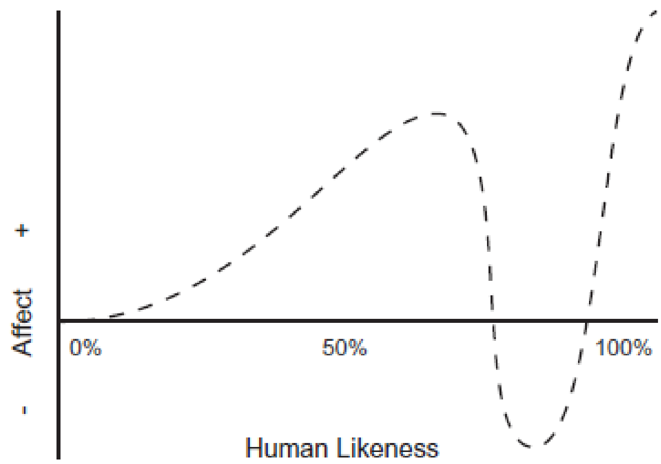


Fig. 1. The uncanny valley function, as proposed by Mori (1970).

2.5 CONCLUSION

Trust is one important element for a successful HRC, therefore trying stimulating it is of utmost importance. Many studies in the past tried to increase robot likeness, acceptance and trust by trying to make robots look or behave more anthropomorphic [24]. Findings show that anthropomorphism can be a promising way to stimulate robot trust and facilitate a successful HRC [1] [2]. Therefore, we decided to use several ways of anthropomorphism to try to facilitate HRC in the use cases of CoLLaboratE. However, as Uncanny Valley theory suggest, anthropomorphism can potentially backfire and fail to yield the expected results. Therefore, we decide to pre-test some of the anthropomorphic techniques which are suitable for the use case, which had not been tested before in previous studies. To test the techniques we designed laboratory studies carefully implementing the techniques and assess their impact on human trust and the acceptance towards robots.

3 STUDIES

3.1 PRELIMINARY STUDY

The goal of the study is to test whether a more anthropomorphic gesture (handshaking) from a robot can create more trust in humans.

3.1.1 Method

The experiment took place in the lab of AUTH with one of their robots. As participants for the experiment we used students of AUTH. 25 participants were invited to the lab (7 Female, M_{age}=21.76, SD=3.36).

3.1.2 Procedure

Participants were randomly assigned to one of the two conditions of the study: 1) non-anthropomorphic condition where participants had to "move" a collaborative robot sideways (left to right and vice versa) and the 2) anthropomorphism condition whether participants had to perform a handshake with the robot. The robot used in the experiment was a KUKA LWR4+ 7dof arm. The method used to program the robot to perform the two actions (non-anthropomorphic and anthropomorphic) was a kinematic control method for human-robot motions which achieves a fast motion synchronization given a preset internal robot handshake motion and a compliance level that reflects the robot's level of passiveness [28]. Fig. 2 demonstrates a handshake with the robot.

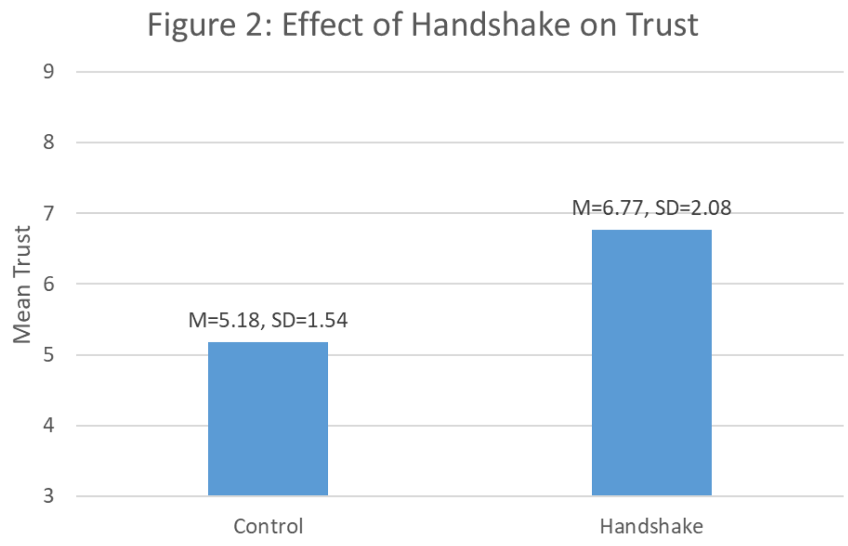
After performing the action with the robot participants were asked the following questions:

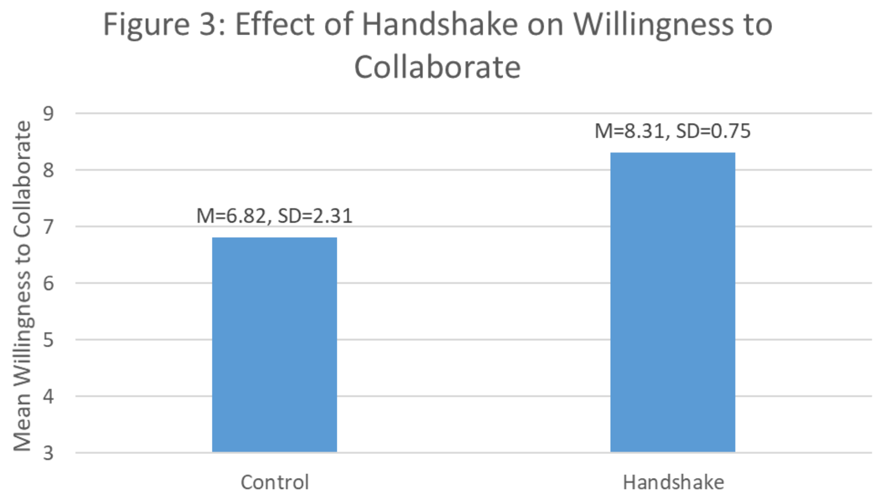
How much do you trust the robot? (1 Not at all – 9 Very much so).
How much do you trust the robots in general? (1 Not at all – 9 Very much so).
How willing would you be to cooperate with the robot? (1 Not at all – 9 Very much so).
How willing would you be to cooperate with the robots in general? (1 Not at all – 9 Very much so).
Last part consisted the demographic questions part (age, gender, level of education).

Fig. 2: Handshake with the robot

3.1.3 Results

The results revealed that handshaking created more trust towards the robot of the study and more willingness to collaborate. As shown in Fig 2 and 3, the difference between the control and the anthropomorphism condition was statistically significant for both trust ($t(23)=-2.190$, $p=0.039$) and willingness to collaborate ($t(23)=-2.520$, $p=0.019$). However, handshake did not create more trust ($t(23)=-0.397$, $p=0.695$) and willingness to collaborate ($t(23)=-0.258$, $p=0.799$) with robots in general.





The results study indicate that handshake can be used to increase the trust and willingness to collaborate with robots. However, the sample size in the present study was quite small. Therefore, we wanted to try to replicate the results in a second study with larger sample.

3.2 Study 1

The goal of study 1 was to try to replicate and extend the results of the preliminary study with larger sample size. The study is currently running and the results are expected somewhere in the beginning of April 2020.

3.2.1 Method

The experiment will take place in the lab of AUTH with one of their robots. As participants for the experiment we used students of AUTH and the neighboring University of Macedonia. The sample size we are opting for is approximately 120 participants.

3.2.2 Procedure

The experiment will include three conditions: 1) control condition where participants will watch the collaborative robot to perform a movement sideways (left to right and vice versa), 2) non-anthropomorphic gesture condition where participants will have to "move" the collaborative robot (made by researchers of Aristotle University, see picture below) sideways (left to right and vice versa) and 3) anthropomorphic gesture condition whether participants will have to do a handshake with the robot.

After that participants will have to answer some self-reported measures about trust, willingness to collaborate with robot and anthropomorphism:

How trustworthy did the robot appear to you? (1 Not at all – 9 Very Much so).
I would trust the robot to do its job (1 I Completely Disagree – I completely Agree).

If given a chance, I think I'll use this robot in the near future (1 I Completely Disagree – I completely Agree).
If given a chance, I'm certain to use this robot in the near future (1 I Completely Disagree – I completely Agree).
If given a chance, I plan to use the robot during in the near future (1 I Completely Disagree – I completely Agree).

How human-like does the robot appears to be (1 Non-human- 9 Very human-like).
How strange/familiar does the robot appears to be (1 Very strange- 9 Very familiar).

Next participants will answer two questions measuring trust in a more objective way:

they will be asked if they want to perform a task where they will let the robot touch their cheek and if they are willing to play the trust fall game with the robot (deliberately allow themselves to fall, trusting the robot to catch them). In actuality the participants will not perform the tasks and the will be debriefed about this deception in the end of the study.

Next, participants will answer to questions from the Individual Differences in Anthropomorphism Questionnaire [14] measuring the tendencies of people to anthropomorphize (see annex 1). Also they will answer questions measuring how introvert/extravert they are [29](see annex 1). We decided to use these two scales to investigate whether individual differences in the tendencies to anthropomorphize and extraversion have an interactive effect with handshaking on trust and willingness to collaborate.

Last part will be the demographic questions part (age, gender, level of education).

4 BIBLIOGRAPHY

[1] Niculescu, A., van Dijk, B., Nijholt, A., Li, H., & See, S. L., "Making social robots more attractive: the effects of voice pitch, humor and empathy," *International journal of social robotics,* vol. 5, no. 2, pp. 171-191, 2013.

[2] Waytz, A., Heafner, J., & Epley, N., "The mind in the machine: Anthropomorphism increases trust in an autonomous vehicle," *Journal of Experimental Social Psychology,* vol. 52, pp. 113-117. , 2012.

[3] International Organisation for Standardisation"Robots and robotic devices - Safety," *Geneva, Switzerland: International Standards,* (2011).

[4] Weidner R, Kong N, Wulfsberg JP, "Human Hybrid Robot: a new concept for supporting," *Production Engineering Research Development,* vol. 7, pp. 675-684, 2013.

[5] Guizzo E, "Three engineers, hunders of robots, one warehouse," *IEEE Spectrum,* vol. 7, no. 45, pp. 26-34, 2008.

[6] Lee, J. D., & See, K. A., "Trust in automation: Designing for appropriate reliance," *Human factors,,* vol. 46, no. 1, pp. 50-80, 2004.

[7] Groom, V., & Nass, C., " Can robots be teammates?," *Human Factors,* vol. 8, pp. 483-500, 2007.

[8] Freedy, A., de Visser, E., Weltman, G., & Coeyman, N., "Measurement of trust in human-robot collaboration," *Proceedings of the 2007 International Conference on Collaborative Technologies and Systems ,* Vols. Orlando, FL: IEEE, p. 106–114, 2007.

[9] Park, E., Jenkins, Q., & Jiang, X., "Measuring trust of human operators in new generation rescue robots.," *7th JFPS International Symposium on Fluid Power,* Vols. Toyama, Japan., 2007.

[10] de Visser, E. J., Parasuraman, R., Freedy, A., Freedy, E., & Weltman, G., "A comprehensive methodology for assessing human-robot team performance for use in training and simulation," *Proceedings of the 50th Annual Meeting of the Human Factors and Ergonomics Society,* vol. Santa Monica. CA: Human Factors and Ergonomics Society, p. 2639–2643, 2006.

[11] Dzindolet, M. T., Peterson, S. A., Pomranky, R. A., Pierce, L. G., & Beck, H. P., "The role of trust in automation reliance," *International journal of human-computer studies,* vol. 58, no. 6, pp. 697-718, 2003.

[12] De Visser, E. J., Monfort, S. S., McKendrick, R., Smith, M. A., McKnight, P. E., Krueger, F., & Parasuraman, R., " Almost human: Anthropomorphism increases trust resilience in cognitive agents," *Journal of Experimental Psychology: Applied,* vol. 22, no. 3, p. 331, 2016.

[13] Madhavan, P., Wiegmann, D. A., & Lacson, F. C., "Automation failures on tasks easily performed by operators undermine trust in automated aids," *Human factors,* vol. 48, no. 2, pp. 241-256, 2006.

[14] Waytz, A., Cacioppo, J., & Epley, N., "Who sees human? The stability and importance of individual differences in anthropomorphism," *Perspectives on Psychological Science,* vol. 5, no. 3, pp. 219-232, 2010.

[15] Epley, N., Waytz, A., & Cacioppo, J. T., "On seeing human: a three-factor theory of anthropomorphism," *Psychological review,* vol. 114, no. 4, p. 864, 2007.

[16] N. Epley, "A mind like mine: the exceptionally ordinary underpinnings of anthropomorphism," *Journal of the Association for Consumer Research,* vol. 3, no. 4, pp. 591-598, 2018.

[17] Leyens, J. P., Paladino, P. M., Rodriguez-Torres, R., Vaes, J., Demoulin, S., Rodriguez-Perez, A., & Gaunt, R., "The emotional side of prejudice: The attribution of secondary emotions to ingroups and outgroups.," 2000.

[18] N. Haslam, "Dehumanization: An integrative review.," *Personality and social psychology review,* vol. 10, no. 3, pp. 252-264, 2006.

[19] Spexard, T., Haasch, A., Fritsch, J., & Sagerer, G., "Human-like person tracking with an anthropomorphic robot.," *Proceedings IEEE International Conference on Robotics and Automation,* vol. ICRA, pp. 1286-1292, 2006.

[20] Bartneck, C., Bleeker, T., Bun, J., Fens, P., & Riet, L., "The influence of robot anthropomorphism on the feelings of embarrassment when interacting with robots.," *Paladyn, Journal of Behavioral Robotics,* vol. 1, no. 2, pp. 109-115, 2010.

[21] Riek, L. D., Rabinowitch, T. C., Chakrabarti, B., & Robinson, P., "How anthropomorphism affects empathy toward robots.," *Proceedings of the 4th ACM/IEEE international conference on Human robot interaction,* pp. 245-246, 2009.

[22] Fussell, S. R., Kiesler, S., Setlock, L. D., & Yew, V., "How people anthropomorphize robots.," *3rd ACM/IEEE International Conference on Human-Robot Interaction (HRI) ,* vol. IEEE, pp. 145-152, 2008.

[23] C. &. S. C. J. Stanton, "Robot pressure: the impact of robot eye gaze and lifelike bodily movements upon decision-making and trust.," *International Conference on Social Robotics ,* pp. 330-339, 2014.

[24] Van Pinxteren, M. M., Wetzels, R. W., Rüger, J., Pluymaekers, M., & Wetzels, M., "Trust in humanoid robots: implications for services marketing," *Journal of Services Marketing,* vol. 33, no. 4, pp. 507-518, 2019.

[25] Baron, R., Logan, H., Lilly, J., Inman, M., & Brennan, M., "Negative emotion and message processing," *Journal of Experimental Social Psychology,* vol. s, no. 2, pp. 181-201, 1994.

[26] Mori, "Bukimi no tani [The uncanny valley]," *Energy,* vol. 7, no. 4, pp. 33-35, 1970.

[27] Wang, S., Lilienfeld, S.O. and Rochat, P., "The uncanny valley: existence and explanations," *Review of General Psychology,* vol. 19, no. 4, pp. 393-407, 2015.

[28] Papageorgiou D & Doulgeri Z, "A kinematic controller for human-robot handshaking using internal motion adaptation. In: IEEE Int Conf on Robotics and Automation," *IEEE Int Conf on Robotics and Automation,* Vols. 5622-5627, 2015.

[29] Soto, C. J., & John, O. P., " The next Big Five Inventory (BFI2): Developing and assessing a hierarchical model with 15 facets to enhance bandwidth, fidelity, and predictive power.," *Journal of Personality and Social Psychology,* vol. 113, pp. 117-143, 2017.

Annex 1

Individual Differences in Anthropomorphism Questionnaire

1 To what extent is the desert lethargic?

2 To what extent is the average computer active?

3 To what extent does technology—devices and machines for manufacturing, entertainment, and productive processes (e.g., cars, computers, television sets)—have intentions?

4 To what extent does the average fish have free will?

5 To what extent is the average cloud good-looking?

6 To what extent are pets useful?

7 To what extent does the average mountain have free will?

8 To what extent is the average amphibian lethargic?

9 To what extent does a television set experience emotions?

10 To what extent is the average robot good-looking?

11 To what extent does the average robot have consciousness?

12 To what extent do cows have intentions?

13 To what extent does a car have free will?

14 To what extent does the ocean have consciousness?

15 To what extent is the average camera lethargic?

16 To what extent is a river useful?

17 To what extent does the average computer have a mind of its own?

18 To what extent is a tree active?

19 To what extent is the average kitchen appliance useful?

20 To what extent does a cheetah experience emotions?

21 To what extent does the environment experience emotions?

22 To what extent does the average insect have a mind of its own?

23 To what extent does a tree have a mind of its own?

24 To what extent is technology—devices and machines for manufacturing, entertainment, and productive processes (e.g., cars, computers, television sets)—durable?

25 To what extent is the average cat active?

26 To what extent does the wind have intentions?

27 To what extent is the forest durable?

28 To what extent is a tortoise durable?

29 To what extent does the average reptile have consciousness?

30 To what extent is the average dog good-looking?

Introvert/Extravert Scale

I am someone who…

1 Tend to be quite

2 Is dominant, acts as a leader

3 Is full of energy

4 Is outgoing, sociable

5 Prefers to have others take charge

6 Is less active than other people