Eye-Tracking-based Wizard-of-Oz Usability Evaluation of an Emotional Display Agent Integrated to a Virtual Environment

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Abstract: This paper presents the results of the usability testing of an experimental component of the Virtual Collaboration Arena (VirCA) developed by the Cognitive Informatics Group of the Computer and Automation Research Institute of the Hungarian Academy of Sciences. This component is a semi-intelligent agent called the Emotional Display Object. We applied Wizard-of-Oz type high-fidelity early prototype evaluation technique to test the concept. The research focused on basic usability problems, and, in general, the perceptibility of the object as uncovered by eye-tracking and interview data; we analyzed and interpreted the results in correlation with the individual differences identified by a demographic questionnaire and psychological tests: the Myers-Briggs Type Indicator (MBTI), the Spatial-Visual Ability Paper Folding Test, and the Reading the Mind in the Eyes Test (RMET) – however, the main goal of this paper outreaches beyond the particular issues found and the development of an agent: it shows a case study on how complex concepts in Virtual Reality (VR) can be tested in very early stage of development.

Keywords: usability evaluation; Wizard-of-Oz; concept testing; early prototype; eye-tracking; human-robot interaction; virtual reality (VR); virtual agent; uncanny valley; individual differences

1 Introduction

The Emotional Display object as a virtual agent was integrated into a 3D virtual environment, the Virtual Collaboration Arena (VirCA) developed by the Cognitive Informatics Research Group of the Computer and Automation Research Institute of the Hungarian Academy of Sciences [1]–[3].

The research team of the Department of Ergonomics and Psychology at the Budapest University of Technology and Economics joined the project in its final phase to study the Emotional Display object in context of use.

1.1 Background of the Tested Emotional Display Agent: The Idea of Ethology-Inspired Robots

People do not like human-like robots, if the robots reach nearly perfect similarity with human robots, according to the "uncanny valley" hypothesis of Mori [4], [5].

Figure 1 shows that if a robot looks and works obviously as a machine, some similarity with humans can support its acceptance by humans in Human-Robot Interaction (HRI). Furthermore, for definitely machine-like robots, it looks true that the more the similarity with humans, the more affinity felt by humans.
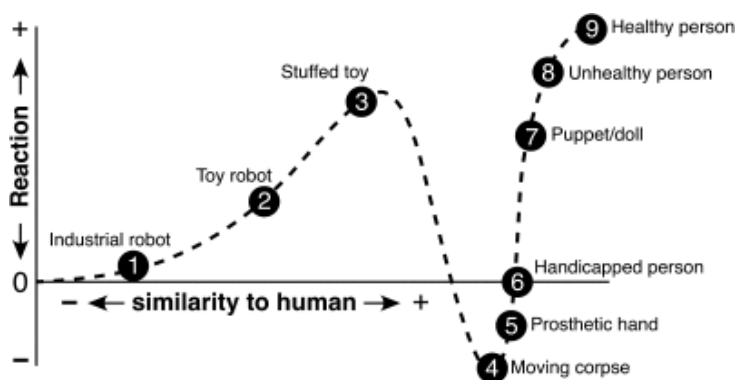
Figure 1

The Uncanny Valley, as Mathur and Reichling [6] adapted the hypothesis from Mori [5], [4]

Theoretically, if a robot is indistinguishable from a human being, humans like to interact with it, as they would do with another real human. However, robots indistinguishable from human beings are parts of a possible future or they are featured in science-fiction novels and movies only, like some androids of the novel "Do Androids Dream of Electric Sheep?" by Philip K. Dick [7] (and the movie titled "Blade Runner" based on it). Until the realization of this – whether this is wanted or unwanted –, if the similarity of a human-like robot gets close to perfect similarity, humans feel uncanny instead of having a positive affinity: in this case, the robot looks to be like a moving corpse or zombie.

So, beside the developments in the direction of human-like humanoid robots [8]–[10], there are other directions to improve HRI. One promising way is the so-called etho-robotics: applying analogous ethological patterns borrowing not from the human-human interactions, but, for example, from the human-dog interactions. The domestication of dogs and more than 30,000 years of living humans and dogs

together resulted behavioural changes in dogs that enhanced the human-dog social interaction. This social competence of dogs may inspire a model for HRI [11]. Miklósi, Korondi, and their colleagues [12] argue that the robots' embodiment and behaviour should fit their specific environments and functions: instead of aiming to build more and more human-like robots, various species can be considered as an analogue.

In this train of thought, we can go further: (1) Human-human interaction as a model for HRI can cause uncanny effect. (2) Human-dog interaction as a model for HRI can be applied, however, selecting the dog form the species can be considered to be arbitrary. (3) Interaction of humans and any existing species having social competence should be generalized. (4) Based on these experiences, social interaction of humans and new, non-human and non-animal type of artificial robots would come into the focus of the developers. One attempt to this generalization was developing a robot with wholly artificial form, but with social ability and behaviour that humans can respect [3], [13], [14]. It could mean a prospective realization of a new level of Human-Machine Interaction according to the Cognitive Infocommunications (CogInfoCom) approach [3], [13].

Researchers of the Department of Ethology at Eötvös Loránd University developed a virtual form consisting of a sphere and labyrinth-like perpendicular lines what can visualize emotions that participants of experiments can identify as emotional states of happiness, despair, fear and anger [13], [14]. So, it looks totally artificial. However, it inherited some behavioural ability from animal analogues to show emotions. (Referring the curve of Figure 1, this virtual "robot" can be placed close to 0 point of the horizontal dimension: it looks much more artificial than a humanoid robot, and looks more artificial than an industrial robot as well.) This always spinning Emotional Display object achieves these emotional states by changing its size, colour, and rotation rate, and pulsation of vertical position ("jumping"). This object is shown in Figure 2 and on the lower left side of Figure 3.

Figure 2

The Emotional Display object applied in this research. It is always spinning. Sometimes, it changes its size, colour, and rotation rate, or starts to pulsate its vertical position ("jumping")

1.2 Related Works 1: Practice of Usability Evaluations in 3D Virtual Environments

In the research published in this paper, we aimed at performing the usability evaluation of a new object of a 3D virtual environment. The term 'usability' and the usability evaluation methods are matured in Human-Computer Interaction (HCI) [15], [16]. Already existing empirical usability evaluations, also in 3D virtual environments, have traditions: some of them focus on interaction styles, such as gesture control [17]; some of them focus on specific features of virtual environments, such as colours [18]; others focus on broad term of usability issues [19]–[24].

1.3 Related Works 2: Experiences on Individual Differences in Usability Evaluations

Usability evaluations often faltered at the level of identifying usability problems in general, without respecting the different needs of various users. However, the myth of "average user" [25] is exceeded by a number of studies involving individual differences, such as cultural background [26], personality types [27]–[29], and cognitive styles [30]–[32]. The current research published in this paper emphasizes the importance of the approach of taking care of individual differences.

2 Methods

2.1 Participants

Eighteen participants were involved, eleven female and seven male between the ages of 20-33 (mean age: 24).

2.2 Experimental Setting

All participants were seated in front of a Tobii T120 eye-tracking device, in the laboratory of the Department of Ergonomics and Psychology. Beyond eye-tracking, the user camera of the Tobii equipment also recorded the participants' facial expressions.

The VirCA software and an intelligent cyber object of the VirCA system, the KUKA robot worked in the user's computer.

The Emotional Display object and a user interface to control its "behaviour" were installed on an adjacent computer. The "behaviour" of the Emotional Display object was simulated by the experimenter following predefined rules and based on the user's behaviour, as it is described below. This Wizard-of-Oz setup is often used in the evaluation of 3D environments, as described by Bowman et al. [33].

The virtual room of the VirCA contained a KUKA-type industrial robot, the tested Emotional Display object, some other objects, and some posters on the walls (Figure 3).

In mechanical engineering, the robot type called "KUKA" refers to a standard construction-type of industrial robots: a robotic arm, where the first axis is vertical, and then the next two axes are horizontal. The "KUKA" name came from the name of the German company that made it widespread in industry. On the margin, the applied virtual robot is a model of a particular, existing industrial robot (KUKA KR 6) made by the mentioned company. The participants were able to control this virtual industrial robot selecting it by a virtual cross-hair, then giving orders by a menu displayed in three dimensions.

Figure 3
The basic layout of the room in VirCA with the KUKA robot, two tables and three balls belonging to the KUKA object, an additional ball, and the tested Emotional Display object on the left side. The poster showing the instructions can also be seen in the background

Around the KUKA robot, other related objects were placed: two tables and three balls. The menu of the KUKA contained a direct command to move a ball from one table to another. An additional (non-working, immobile) ball was placed on one of the tables of the KUKA.

The tested Emotional Display Object was also placed close to the industrial robot. It looked as it was described at the end of the Section 1.1 (Figure 2).

There were two additional objects (a domino and another ball) on the floor in the middle of the room. There were posters hanging on the walls. One of them showed the instructions for the participants.

2.3   Procedure

After the instructions, the participants completed three tasks with the VirCA:

1) The first task was to look at the posters on the walls at a glance just to practice a basic navigational task.

2) Then they had to delete two objects in the room using the menu to become more familiar with the object selection and menu functions.

3) Finally, they had to go to a given position and turn to a given direction to recreate the initial view they saw upon entering the space. This is how we ensured that the Emotional Display Object stayed in sight while the participant performed the actions. From this position, they had to command the industrial robot to move three balls from one table to another.

The overall position of the Emotional Display object was stationary all through the session, although it was not motionless. When it was idle, it had a continuous rotation; and, when it was in specific non-idle states, it changed its size, colour, and/or rotation speed as defined by its emotional state [13], [14]. The Emotional Display object had three emotional states thus behaving like an intelligent agent although operated by a human in the Wizard-of-Oz setup.

The predefined rules of the behaviour of the Emotional Display Object were the following:

• It showed the "happy" animation (animations were based on previous research [13], [14]) several times: first when the participant first saw the space, next when it was mentioned during the briefing, and then every time the participant succeeded in moving a ball.

• There were two other emotion animations, which were played in specific situations. If a participant failed to move a ball from one table to another in three tries, the Emotional Display Object displayed the "sad" animation. If someone failed to move a ball five times or made many wrong attempts at interacting with the system, it showed the "angry" animation.

As they were highly situational, most participants did not have the chance to see them. After the participants finished these tasks, they were interviewed about their experience with the system and completed several questionnaires:

- demographic questionnaire on their experience regarding First-Person Shooter and Simulator games or any other software that requires manipulating 3D environments (AutoCAD, etc.) and their experience with pets (what kind of pets and for how long did they have them),

- the RMET (Baron-Cohen's Reading the Mind from Eyes Test [34]),

- a standard Paper-Folding Test [35],

- and the Hungarian version MBTI (Myers-Briggs Type Indicator [36]).

Our hypotheses were the following. First, we expected the participants with better spatial skills and more experience with 3D manipulation to be better at detecting any changes happening to the Emotional Display Object. We also expected that participants with higher RMET values to be able to recognize emotions simulated by the Emotional Display more easily. We also hypothesized that the longer time the participant had pets in the past, the more accurate his/her thoughts will be regarding the emotional state and overall functionality of the Emotional Display.

2.4   Statistical Analysis

Because of the type of the variables and the small number of cases, the connections between the variables were tested by carefully selected methods:

- In cases of testing connections between scale and ordinal variables, Spearman's ρ (rho) correlation coefficients were calculated.

- In cases of testing differences between values grouped by dichotomy variables (comparing distributions across groups using grouping variable with two discrete values), non-parametric Mann-Whitney U tests were applied.

Statistical analyses were performed using the IBM SPSS Statistics software, version 22.0.

3　Results

3.1　Perceiving the Changes of the State of the Emotional Display Object

As the post-experiment interviews and eye-tracking data revealed, most of the participants did not see any change in the state of the Emotional Display Object at all. All were aware of the Emotional Display Object's presence, because we mentioned it in the briefing as the representation of the industrial robot. However, most of the participants did not care to look at it during the tasks. This was somewhat expected based on earlier research [37]–[40]. The effect of selective attention can be quite powerful. A new task can use up all of the available attentional resources. This makes the participants focus only on the most important parts of the screen (Figure 4).

Figure 4

Eye-tracking heat map of a typical interaction. Note that fixations only appear at areas needed exclusively for the task

The surprising fact was that even when people fixated on the Emotional Display for a long time (4-5 s, Figure 5) while it was animated, they still were not able to report any changes in its behaviour during the post-experiment interviews.

Figure 5
Fixating on the Emotional Display while its animating didn't ensure that the participant noted any
changes

We also found that visibility may have been an issue. In its idle state, the Emotional Display differed from its background in colour. However, as you can see in Figure 6, as it plays the "happy" animation, its colour almost matches that of the background. This clearly worsened the visibility of the Emotional Display Object in a state when we wanted participants to notice it.

Also, the way the "happy" animation is presented made it more difficult to spot the Emotional Display. With the start of the animation, the object's inner wire structure shrunk in size and levitated towards the floor. This, on some occasions, made some of its lower section to sink into the floor.

Since users could not interpret the emotions of the Emotional Display Object, we analyzed their ability to simply perceive and recognize the changes in the Emotional Display Object in the space.
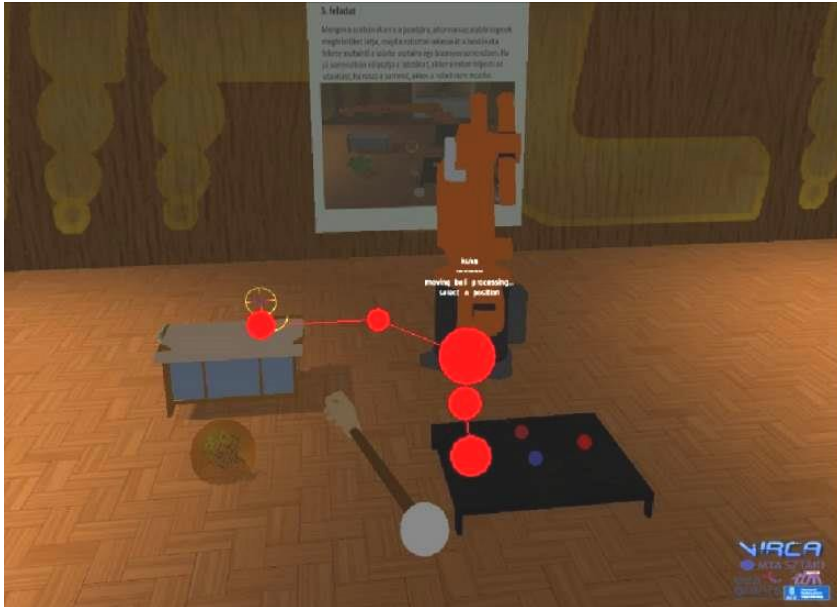
Figure 6

The Emotional Display object during the "happy" animation. The series of the fixations marked by the red dots show that the glaze of the user kept off the Emotional Display object in spite of its changing state

3.2 Factors Impacting the Observation of the Emotional Display Object

We found a significant correlation between the number of fixations on the Emotional Display being in its idle state and in its animated state (Spearman's $\rho = 0.779$, $p = 0.000$). This result means that the changes in its movement, size, shape, and colour did not draw any attention. This finding suggests that if someone noticed the Emotional Display Object at all then he/she looked at it more often irrespective of the movements and changes in it, and thus had a better chance of seeing its animations.

According to the scores of the MBTI psychological test, participants characterized with Feeling instead of Thinking fixated significantly longer (Spearman's $\rho = 0.622$, $p = 0.006$), and for more often (Spearman's $\rho = 0.553$, $p = 0.017$) on the Emotional Display Object.

Participants characterized more by Intuition than by Sensation also looked at the Emotional Display Object more often (Spearman's $\rho = 0.459$, $p = 0.055$).

3.3 Factors Impacting the Observation of the Emotional Display Object's Changes

We found a significant correlation between participants' ability to connect the changes of the Emotional Display Object's state to a particular action or event and the length of owning pets (Spearman's $\rho = 0.423$, $p = 0.040$, Figure 7).
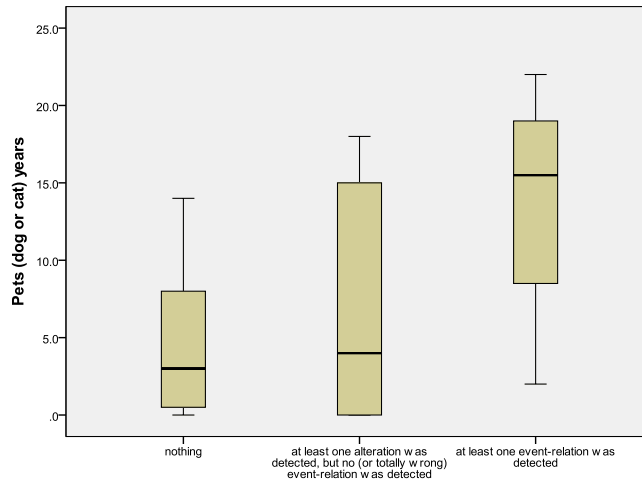

Figure 7

If the participants are grouped by their ability to connect the changes of the Emotional Display object's state to a particular action or event, significant correlation can be identified: the longer time one had pets, the better his/her ability is to recognize the Emotional Display object's reactions.

Spearman's $\rho = 0.423$, $p = 0.040$

It seems that the longer a participant had pets, the better his/her ability was to recognize the Emotional Display Object's reactions. This result is promising for the future development of the Emotional Display Object.

The results of the Spatial-Visual Paper Folding Test also correlated strongly (Spearman's $\rho = 0.638$, $p = 0.004$) with recognizing changes in the Emotional Display Object. The better the test result was, the more likely the participant was to attribute the observed change to some other action.

3.4 A Sample Usability Problem

A frequently occurring usability problem was passing the pointer hand through the object. This prevented the pointer from selecting the object.
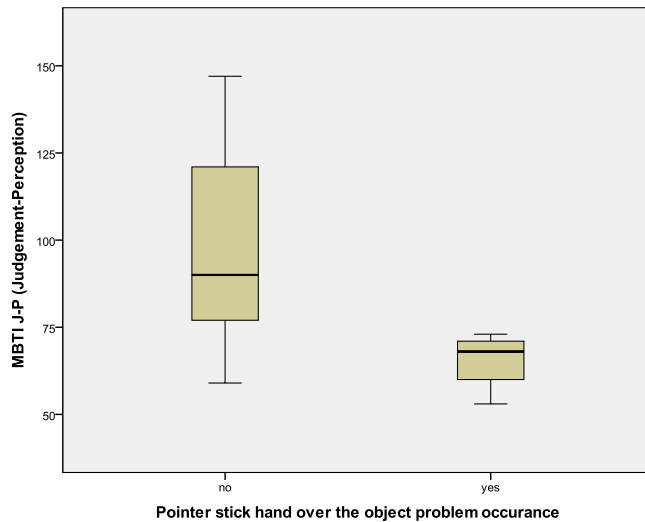
Figure 8

According to the scores of the Myers-Briggs Type Indicator (MBTI) psychological test, participants characterized by Judgment instead of Perception were more likely to make this mistake as a trend ($p = 0.022$)

We identified a significant connection between the occurrence of this problem and a cognitive style dimension of the MBTI test: participants characterized by Judgment instead of Perception were more likely to make this mistake as a trend (Mann-Whitney's U test, $p = 0.022$, Figure 8).

3.5 Confusion between the Role of the Emotional Display Object and the KUKA Industrial Robot

Another frequently occurring problem was that some of the users selected the Emotional Display Object instead of the KUKA industrial robot to command the robot. This happened in spite of the participants being instructed: "This rotating structure is a small creature *who* is a representation of the internal state of the robot."

We identified a tendency-like connection between the occurrence of this problem and a cognitive style dimension of the MBTI test: participants characterized by Thinking instead of Feeling were more likely to make this mistake as a trend (Mann-Whitney's *U* test, $p = 0.088$, Figure 9).

Those who avoided this problem were more likely to notice changes in the Emotional Display object (Mann-Whitney's *U* test, $p = 0.019$).
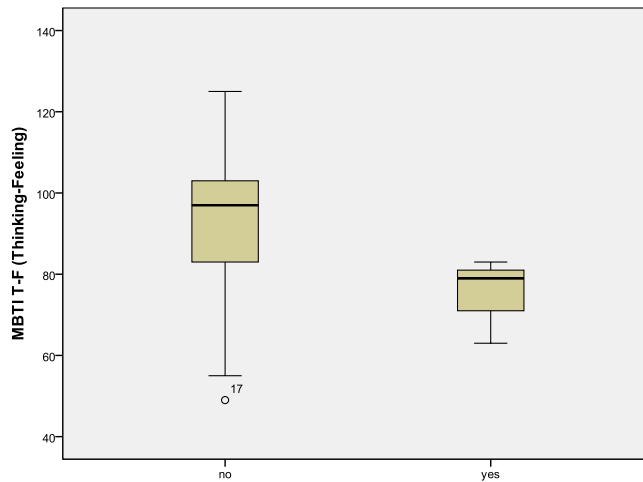
Figure 9

Distribution of the scores of the Thinking-Felling scores of the Myers-Briggs Type Indicator (MBTI) psychological test in cases when the users were confused between the role of the Emotional Display object and the KUKA industrial robot or not. The difference is not significant, but can be considered as a tendency ($p = 0.088$)

4   Discussion and Suggestions

The users were too focused on their tasks to notice the Emotional Display Object. A possible explanation of this is that the users in our experiment were all inexperienced in the use of the environment and did not have a chance to spend longer practicing the interaction methods. As previously demonstrated in the literature [37]–[40], selective attention can be a powerful effect in given circumstances. In longer and/or multiple interaction sessions users could gain significantly more experience with the interaction. This experience would reduce their cognitive load resulting from the interaction and better allow them to observe and recognize the Emotional Display Object. Thus, a study with multiple interaction sessions may result in different perceptions.

The Emotional Display Object's lack of movement may have also contributed to its "invisibility" to some of the participants. Our original idea included a moving agent that could have guided the gaze of the participants by flying closer to objects relevant to the task at hand.

This dynamic location changing behaviour of the Emotional Display Object could make it more visible and functional. Its motion alone would draw more attention to it while directing the gaze of the participant to the objects required to finish a

task. In its current, stationary form, it often leaves the users field of view. By dynamically adjusting to the field of vision (by constantly staying in the lower left or right corners of the screen), it would assure its visibility. Beyond that it would not seem like just another object in the virtual space but it could be a part of the user interface. This, however, could not have been implemented by the time of our data collection.

The development process can continue in a new VR environment: the successor of the VirCA system applied now is the MaxWhere VR platform [41]–[44] that promises new prospects.

On the grounds of our research, further ideas of development can be produced that can later be evaluated in a set of studies that would also incorporate the lessons learned for the evaluation of 3D spaces. The lessons learned from this research have outreached beyond the particular issues found and the development of an intelligent object: this case study have shown a successful practice of methods capable of testing complex concepts in Virtual Reality (VR) in very early stage of development.

Acknowledgement

References

[1]   Á. Vámos, I. Fülöp, B. Reskó, and P. Baranyi, Collaboration in Virtual Reality of Intelligent Agents. Acta Electrotechnica et Informatica, Vol. 10, No. 2, pp. 21-27, 2010

[2]   Á. Vámos, B. Reskó, P. Baranyi. Virtual Collaboration Arena. In Proceedings of SAMI 2010, 8th IEEE Int. Conference on Applied Machine Intelligence and Informatics (Herlany, Slovakia, Jan. 28-30, 2010), pp. 159-164, IEEE, 2010

[3]   P. Baranyi, A., Csapo, and G. Sallai, Cognitive Infocommunications (CogInfoCom), pp. 73-102, Cham: Springer, 2015

[4]   M. Mori, The uncanny valley, Energy, Vol. 7 4:33-35, 1970 (in Japanese)

[5]   M. Mori, The Uncanny Valley (translated by K. F. MacDoman and N. Kageki), IEEE Robotics & Automation Magazine, Vol. 19, No. 2, pp. 98-100, June 2002

[6]   M. B. Mathur and D. B. Reichling, Navigating a social world with robot parners: A quantitative cartography of the Uncanny Valley, Cognition, Vol. 146, pp. 22-32, January 2016

[7]   P. K. Dick, Do Androids Dream of Electric Sheep? Doubleday Science Fiction, Garden City, New York: Doubleday & Company, Inc., 1968

[8]   D. Benson, M. M. Khan, T. Tan, and T. Hargreaves, Modeling and Verification of Facial Expression Display Mechanism for Developing a Social Robot Face, Proceedings of ICARM 2016, International Conference on Advanced Robotics and Mechatronics (Macau, China, Aug 18-20, 2016), pp. 76-81, IEEE, 2016

[9]   B. Borovac, M. Gnjatovic, S. Savic, M. Rakovic, and M. Nikolic, Human-like Robot MARKO in the Rehabilitation of Children with Cerebral Palsy, In H. Bleuler, M. Bouri, F. Mondala, D. Pisla, A. Rodic, and P. Helmer (eds.), New Trends in Medical and Service Robots, Mechan. Machine Science, Vol. 38, pp. 191-203, Cham: Springer, 2016

[10]   N. Paine, J. S. Mehling, J. Holley, N. A. Radford, G. Johnson, C.-L. Fok, and L. Sentis: Actuator Control for the NASA-JSC Valkyrie Humanoid Robot: A Decoupled Dynamics Approach for Torque Control of Series Elastic Robots, Journal of Field Robotics, Vol. 32, No. 3, pp. 378-396, May 2015

[11]   C. I. Szabó, A. Róka, M. Gácsi, Á. Miklósi, P. Baranyi, and P. Korondi. An Emotional Engine Model Inspired by Human-Dog Interaction. In Proceedings of 2010 IEEE International Conference on Robotics and Biomimetics (Tianjin, China, Dec 14-8, 2010), pp. 567-572, IEEE, 2010

[12]   Á. Miklósi, P. Korondi, V. Matellán, and M. Gácsi, Ethorobotics, A New Approach to Human-Robot Relationship, Frontiers in Psychology, Vol. 8, article 958, 8 pages, Jun 2017

[13]   G. Persa, A. Csapo, and P. Baranyi, A Pilot Application for Ethology-based CogInfoCom Systems, In Proceedings of SAMI 2012, 10th IEEE Jubilee International Symposium on Applied Machine Intelligence and Informatics (Herl'any, Slovakia, Jan. 26-28, 2012), pp. 474-482, IEEE, 2012

[14]   B. Korcsok, V. Konok, Gy. Persa, T. Faragó, M. Niitsuma, Á. Miklósi, P. Korondi, P. Baranyi, and M. Gácsi, Biologically Inspired Emotional Expressions for Artificial Agents, Frontiers in Psychology, Vol. 9, article 1191, 17 pages, July 2018

[15]   J. Lazar, J. H. Feng, and H. Hochheiser, Research Methods in Human-Computer Interaction, 2nd ed., Cambridge, MA: Morgan Kaufman, 2017

[16]   J. Sauro and J. R. Lewis, Quantifying the User Experience, 2nd ed., Cambridge, MA: Morgan Kaufman, 2016

[17]   F. W. Simor, M. R. Brum, J. D. E. Schmidt, R. Rieder, A. C. B. De Marchi, Usability Evaluation Methods for Gesture-Based Games, JMIR Serious Games, Vol. 4, No. 2, article e17, 17 pages, 2016

[18]   C. Sik-Lanyi, Styles or Cultural Background does Influence the Colors of Virtual Reality Games? Acta Polytechnica Hungarica, Vol. 11, No. 1, pp. 97-119, 2014

[19]   A. Cöltekin, I. Lokka, and M. Zahner, On the Usability and Usefulness of 3D (Geo)Visualizations – A Focus on Virtual Reality Environments, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XLI-B2, pp. 387-392, 2016

[20]   D. Egan, S. Brennan, J. Barrett, Y. Qiao, C. Timmerer, and N. Murray, An evaluation of Heart Rate and ElectroDermal Activity as an objective QoE evaluation method for immersive virtual reality environments. In Proceedings of QoMEX 2016, 8th International Conference on Quality of Multimedia Experience (Lisbon, Portugal, Jun 6-8, 2016), 6 pages, IEEE, 2016

[21]   I. Heldal, The usability of collaborative virtual environments: Towards an evaluation framework. Saarbrücken, Germany: Lambert Academic Publishing AG & Co., 2010

[22]   K. Stanney (1995). Realizing the full potential of virtual reality: human factors issues that could stand in the way. In Proceedings Virtual Reality Annual International Symposium '95 (Research Triangle Park, NC, USA, March 11-15, 1995), pp. 28-34, IEEE, 1995

[23]   K. M. Stanney, R. R. Mourant, and R. S. Kennedy, Human Factors Issues in Virtual Environments: A Review of Literature, Presence, Vol. 7, No. 4, pp. 327-351, Aug 1998

[24]   E. Lógó, B. P. Hámornik, M. Köles, K. Hercegfi, S. Tóvölgyi, and A. Komlódi, Usability related human errors in a collaborative immersive VR environment. In Proceedings of CogInfoCom 2014 – 5th IEEE Conference on Cognitive Infocommunications (Vietri sul Mare, Italy, Nov. 5-7, 2014), pp. 243-246, IEEE, 2014

[25]   S. G. Ruiz, Designing for the extremes (or why your average user doesn't exist), SuGoRu – A blog by S. G. Ruiz, 2013, https://sugoru.com/2013/07/14/designing-for-the-extremes/

[26]   Komlodi and K. Hercegfi, K., Exploring Cultural Differences in Information Behaviour Applying Psychophysiological Methods. In Proceedings of CHI2010 – ACM Conference on Human Factors in Computing Systems (Atlanta, GA, USA, April 10-15, 2010) pp. 4153-4158, ACM, 2010

[27]   A. Dillon and C. Watson, User Analysis in HCI – the historical lessons from individual differences research, International Journal of Human-Computer Studies, Vol. 45, No. 6, pp. 619-637, December 1996

[28]   P. Kortum and F. L. Oswald, The Impact of Personality on the Subjective Assessment of Usability, International Journal of Human-Computer Interaction, Vol. 34, No. 2, pp. 177-186, 2018

[29]   A. Alnashri, O. Alhadreti, and P. J. Mayhew, The Influence of Participant Personality in Usability Tests, International Journal of Human-Computer Intereaction, Vol. 7, No. 1, pp. 1-22, 2016

[30]   E. Nisiforou and A. Laghos, Field Dependence–Independence and Eye Movement Patterns: Investigating Users' Differences Through an Eye Tracking Study, Interacting with Computers, Vol. 28, No. 4, pp. 407-420, 2016

[31]   K. Hercegfi, Event-Related Assessment of Hypermedia-Based E-Learning Material With an HRV-based Method That Considers Individual Differences in Users. International Journal of Occupational Safety and Ergonomics, Vol. 17, No. 2, pp. 119-127, 2011

[32]   K. Hercegfi, O. Csillik, É. Bodnár, J. Sass, and L. Izsó, Designers of Different Cognitive Styles Editing E-Learning Materials Studied by Monitoring Physiological and Other Data Simultaneously. In Proceedings of 8th International Conference on Engineering Psychology and Cognitive Ergonomics: Held as Part of HCII2009 (Human-Computer Interaction International 2009) (San Diego, California, USA, July 14-24, 2009), pp. 179-186, Springer, 2009

[33]   D. A. Bowman, E. Kruijff, J. J. LaViola, and I. Poupyrev. 3D User Interface: Theory and Practice. Boston: Addison-Wesley/Pearson Education, pp. 87-134, 2005

[34]   S. Baron-Cohen, The Essential Difference: The Truth About The Male And Female Brain. New York: Basic Books, 2003

[35]   R. B. Ekstrom, J. W. French, H. H. Harman, and D. Dermen: Manual for kit of factor-referenced cognitve tests 1976, Princeton, NJ: Educational Testing Service, 1990

[36]   L. Izsó, I. Takács. Users' Manual of Myers-Briggs Type Indicator (MBTI) (Myers-Briggs Típus Indikátor (MBTI) felhasználói kézikönyve). Manuscript in Hungarian. Department of Ergonomics and Psychology, Technical University of Budapest (later: Budapest University of Technology and Economics), 1997

[37]   C. Chabris, D. Simons: The Invisible Gorilla: How Our Intuitions Deceive Us. New York: Crown Publishers, 2010

[38] C. Chabris, D. Simons: Selective Attention Test. Video demonstration. 1'22". http://www.youtube.com/watch?v=vJG698U2Mvo

[39] H. Schaumburg, Computer as Tools or as Social Actors? – The Users' Perspective on Anthropomorphic Agents. International Journal of Cooperative Information Systems, Vol. 10, No. 1-2, pp. 217-234, 2001

[40] D. M. Wegner, The Illusion of Conscious Will. Cambridge, MA: MIT Press, 2002

[41] K. Biró, Gy. Molnár, D. Pap, and Z. Szűts, The effects of virtual and augmented learning environments on the learning process in secondary school. In Proceedings of 8th IEEE International Conference on Cognitive Infocommunications (Debrecen, Hungary, Sep. 11-14, 2017), pp. 371-376, IEEE, 2017

[42] T. Budai and M. Kuczmann, Towards a Modern, Integrated Virtual Laboratory System, Acta Polytechnica Hungarica, Vol. 15, No. 3, pp. 149-173, 2018

[43] I. Horvath and A. Sudar, Factors Contributing to the Enhanced Performance of the MaxWhere 3D VR Platform in the Distribution of Digital Information, Acta Polytechnica Hungarica, Vol. 15, No. 3, pp. 191-204

[44] V. Kövecses-Gősi, Cooperative Learning in VR Environment, Acta Polytechnica Hungarica, Vol. 15, No. 3, pp. 205-224, 2018