EEGs as potential predictors of virtual agents' acceptance

Betul Tolgay
Dept of Psychology
Università della Campania "Luigi Vanvitelli"
Caserta, Italy
betul.tolgay@unicampania.it

Silvia Dell'Orco
Dept of Humanistic Studies
Università di Napoli "Federico II"
Naples, Italy
silvia.dellorco@unina .it

Mauro N. Maldonato
Dept of Neuroscience
Università di Napoli "Federico II"
Naples, Italy
nelsonmauro.maldonato@unina.it

Carl Vogel
School of Computer Science and Statistics
Trinity College
Dublin, Ireland
vogel@tcd.ie

Luigi Trojano
Dept of Psychology
Università della Campania "Luigi Vanvitelli"
Caserta, Italy
luigi.trojano@unicampania.it

Anna Esposito
Dept of Psychology
Università della Campania "Luigi Vanvitelli"and IIASS
Caserta, Italy
iiass.annaesp@tin.it

***Abstract*— Over the last decade, much effort has been made to develop robots and virtual agents acting as assistants of elderly people in order to support them in their daily activities. In this context users' acceptance of such virtual assistants is fundamental for engaging them in order to maximize the assistance's effectiveness and users' comfort. Therefore, improving assessment techniques for elders' acceptance of virtual agents is necessary for understanding the impressions they arouse and determining their design accordingly. This paper is a proposition to introduce an EEG emotion detection procedure to gain further insight in implementing effective virtual agents' acceptance.**

Keywords—Assistive technologies; Human-robot interaction; Users' acceptance, EEG, Affective-motivational states, Preference prediction

I. INTRODUCTION

Increasing physical limitations and age-dependent cognitive decline causes many barriers in the lives of older adults. In the last decade much effort has been made to offer solutions to challenges experienced by elderly populations, addressing issues such as independent living and rehabilitation. Mainly, two technologies have emerged to ease the daily life of elderly: material robots and virtual agent assistants.

Assistive robots have been designed for supporting daily activities such as eating, and taking medications, and pet-like robots have been developed to offer social support and companionship [1]. In contrast, virtual agent assistants have been developed and popularized (e.g., Amazon Echo or Alexa), offering to their users the opportunity to set and manage alarms, schedule reminders for medications and order food [2-3]. In addition, medical agents (such as "Fredrick") have been designed for mobile phones to assist diabetes patients to track blood sugar levels, set reminders and shares their data with family members and doctors [4], as well as fixing the agenda for doctor's appointments (see also, "Billie") [5], even though seniors showed some acceptance barriers toward these technologies [6].

Even with some limitations on acceptance, findings show that virtual human assistants are considered more useful than robots by the elderly population. Firstly, research conducted to examine familiarity with technological devices among the elderly shows that their favorite device is the smartphone due to its ease of use [7]. Secondly, android robots very similar in appearance and behavior to humans can cause perceptual disruptions on the user called 'uncanny valley effects' [8, 9]. Lastly, virtual human assistants are more cost effective than robots and do not suffer of a negative perception [10-12].

For developing successful virtual agent assistants, it is essential to understand elderly people's requirements and expectations to increase the level of acceptance. The technology acceptance concept was introduced by Davis, which also provided a Technology of Acceptance Model (TAM) for assessing perceived usefulness and ease of use [13] of interactive systems. TAM was further improved by the addition of two theoretical constructs concerning user's work goals and user's social influence [14]. To investigate intention of use, the fun and pleasure users derived from using a technology (hedonic motivations), as well as perceived benefits and costs, a further questionnaire was developed (UTAUT2, Unified Theory of Acceptance and Use of Technology systems) [15]. Finally, in the Almere [16] and AttrakDiff questionnaire [17, 18], variables that relate to social interaction with robots and virtual agents have been considered.

However, few of the user acceptance studies focused on the elderly population [7, 19]. Along this line of investigation, it is worth mentioning the EMPATHIC project aimed at developing new models to boost interactional exchanges between virtual agents and seniors. To this aim, inside the project a new questionnaire (the Virtual Agent Assistant Questionnaire - VAAQ) has been developed accommodating of all the

previously mentioned concepts, as well as, including new theoretical considerations about needs and requirements of seniors [19].

The VAAQ has been developed accounting of factors of user acceptance suggested as in the AttakDiff questionnaire, such as

- Pragmatic Qualities: Usefulness, usability, and accomplishment of tasks by the proposed agent.
- Hedonic Qualities-Identity: Agent's Pleasantness
- Hedonic Qualities-Feeling: Positive and negative feelings aroused by the agent
- Attractiveness: Attractiveness and engagement of the agent

In addition, the questionnaire provides sections assessing seniors' preferences regarding the social and physical appearance of the agent, including face, voice, age, gender, professions entrusted, and agent's attractiveness.

Findings from the EMPATHIC project showed that besides the practical utility, there are many other factors that should be taken into consideration to engage elders using virtual assistants. For instance, the agent's gender and physical appearance play an important role on seniors' acceptance [7, 19-21].

Developing questionnaires for measuring users' intentions and preferences in order to learn how to improve the quality of the user-agent interaction is useful. However, it might not suffice to give concrete hints into the best design of such assistive technologies. Some relevant variables may not be effectively investigated using questionnaires. For example, rather than investigating practical use and effects of agents' traits on users, it may be important to obtain a proof of the users' affective and motivational states during interactions. In addition, assessing attitudes and affective responses towards virtual agents by combining multiple evaluation methods can enhance the understanding of users' requests and intention to use. To this aim, the present work proposes the use of EEGs measurements, besides questionnaires, as a useful tool for providing additional highlights on user's experience and motivations, by measuring users' arousal of negative/positive affect and their motivational approaches [22, 23]. EEGs can also be useful to add more realistic measures of the uncanny valley effects [24-27]. EEG-based preference prediction is popular in consumer and neuromarketing research [28].

In the following section, we provide motivations that explain why EEG should be proposed for assessing users' acceptance of virtual agents.

II. EEG AS A PREDICTOR OF USER'S ACCEPTANCE

A. EEG distinguishes positive-negative affect and approach-avoidance motivation

Frontal EEG asymmetries have frequently been associated with motivational and affective states. According to the approach/withdrawal model, relatively greater right frontal activation should generally result in a withdrawal-oriented action while greater left frontal activation should result in approach orientation [29]. This motivational model of frontal cortical asymmetry overlaps with the valence model stating that relatively greater right (left) frontal activation is linked to negatively (positively) valenced emotions [30]. Within both the valence and approach/withdrawal models, frontal EEG asymmetries have been associated with both trait-like (such as personality traits) and state-dependent processes (such as moods) [29-34].

Research has suggested a causal relationship between frontal alpha asymmetry and affective valence/motivation. Davidson and Fox examined frontal EEG activity of 10-month-old infants watching video-clips of an actress displaying sad or happy facial expressions, and they found that infants had greater relative left frontal activity to the happy rather than sad face [35]. Similarly, Ekman and Davidson [36] tested undergraduate students and found that facial expressions of genuine smiles caused greater relative left frontal activity than facial expressions of non-genuine smiles.

Some researchers suggest that left frontal activity is related to approach motivation [37, 38]. For testing this idea, prior to presenting pictures of desserts, participants' self-reported liking of those desserts and the time since they had last eaten them were assessed. Results indicated that individuals with stronger emotive tendencies (more liking of desserts, longer time since having eaten the desserts) had greater relative left frontal activity to dessert stimuli compared to neutral stimuli. These results suggest that relative left-frontal activity indicate individual differences toward stimuli (e.g., liking desserts) even though some stimuli may be sufficiently strong to activate motivations in participants [37]. For instance, in a similar study where erotic pictures were used, results showed that such erotic stimuli evoked relative left frontal activation in all male participants [38].

There is also considerable research which has identified that event-related potential components (ERP) are modulated by the valence or/and arousal of emotional pictures [39]. One of these components is the late positive potential (LPP) which emerges approximately 300 to 1000 ms (middle LPP) and from 1000 to 2000 ms (late LPP) after the stimulus onset [39]. Importantly, LPP amplitudes have been shown to be sensitive to highly arousing pictures, both in an aversive and appealing manner [40, 41]. In many studies, LPP amplitudes were found to be higher for motivationally relevant pictures than neutral pictures [41-44] and are a reliable index for motivated attentional processing [39, 40, 45, 46]. Moreover, negative socially relevant concepts evoke higher right-frontal LPPs whereas positive socially relevant concepts evoke larger left-frontal LPPs [47]. In addition, approach-motivated both positive and negative pictures (anger) evoke higher left-frontal LPP amplitudes than neutral pictures [42]

Schillbach et al. [48] studied social interaction in virtual environment and results showed that participants' approach motivations (willingness of interaction) towards other virtual characters were correlated with their asymmetrical activity on

prefrontal dorsolateral cortex (DL-PFC) [48]. Another study collected Functional Near-Infrared Spectroscopy (fNIRS) signals from DL-PFC. By applying brain-computer-interfaces (BCI) techniques, the study tried to match participants' facial emotional expressions with virtual agent's facial expressions. To this aim, participants were instructed to have positive thoughts and make positive facial expressions and the system passed the obtained participants' fNIRS to a control network which using fNIRS values would generate a matching virtual agent's behavior, producing the appropriate facial expressions [49].

B. EEG-based preference prediction

EEG-based emotion classification has been used as preference prediction by categorizing some EEG components related to approach motivation/ positive affect such as 'like' versus EEG components related to negative affect /avoidance motivation such as 'dislike' [50].

In [28], participants' EEG responses were recorded while watching commercials of six different products. Results showed that EEGs had the predictive power of marketing questionnaires completed by participants. Moreover, EEG measures were more successful than questionnaires in predicting commercials' products' success.

In [51] EEGs were used to predict consumer's future choices. This was done by first presenting consumer products during EEG recordings and then asking participants to choose between pairs of previously seen products. Findings showed that weaker theta band amplitudes in the mid-frontal electrode and the N200 component correlate with the individual's more preferred products. Similarly, a research conducted using EEG for aesthetic preference recognition of 3D bracelets showed that EEG data allowed 80% accuracy in classifying liked and disliked products [52].

In [53], a neuro-marketing research was proposed to index impressions of video commercials by tracking cerebral activity related to cognitive tasks such as memorization and attention. Findings show that the proposed approach was successful in judging whether videos were impressive [53].

Ravaja et al. [54] investigated individual's approach motivation as indexed by EEG asymmetry over the frontal cortex while participants were presented 14 different grocery products. First, participants were presented each product individually. Then participants were asked to choose between two different previously seen products. Results showed higher approach motivations (relatively greater left frontal activation) towards desired products during the pre-decision period (first phase of the experiment). Relatively greater left EEG asymmetry was found to be correlated with approach motivation of participants towards their preferred predicting participants affirmative purchase decisions. Moreover, the study reported that higher perceived quality and higher perceived need for a product evoked greater relative left frontal activation.

III. Relations to other works in Cognitive InfoCommunications

Other work in the CogInfoCom sphere has also paid direct attention to the importance of assessing acceptance of new technologies within distinctive demographic groups. Tasevski, et al. [57], for example, address receptiveness of children with cerebral palsy to robots, but measures receptiveness in terms of interaction variables, a species of the measures of use within TAM models, as discussed in the introduction. This is similar to the approach taken by Dautenhahn and colleagues in approaching the development of robots for children with autism [58]. Both use external behavioural use measures, without measuring internal brain states, as proposed here.

EEG signals as informative of user preferences is also implicit in research that incorporates EEG signal monitoring into brain-computer interfaces (BCI) [59]. A review of approaches to developing assistive technologies for people with non-standard cognitive characteristics been provided, and notes BCI within this [60]. While BCI research makes the shared assumption that the EEG signal is important as a proxy indication of user intent, it does not necessarily share the assumption that the signal conveys user acceptance of the technology. Rather, it seems necessary for BCI research to either assume acceptance or identify distinct components within the signal and different signalling regions and timings to separate acceptance of the technology from choices that need to be made while using the technology.

Conclusion

The World Health Organisation (WHO) defines 'Healthy Ageing' as a process of developing and maintaining functional ability that enables well-being among elders [55]. Several technologies have been developed to assist the elderly population to meet their basic needs and research shows that virtual agent assistants are potentially beneficial for them [7-12]. Improving the way virtual agents can provide assistance to elders is not an easy task, and many more research efforts are needed to implement engaging and trustworthy interactions between virtual agents and users in general, and seniors in particular. Seniors' acceptance of such technologies is essential for successful and effective assistance.

Traditional methods such as questionnaires, interviews and focus groups are widely used to investigate user's acceptance of virtual agents. However, developing trustworthy and engaging virtual assistants may need more sophisticated user's information to identify factors essential for making the user/agent interaction successful. Typical research on user's acceptance of virtual agents is done by showing participants several differently appearing agents, with

different gender, different physical features, different facial expressions, in voice/mute conditions. Questionnaires are then administered to participants, after the presentation of each agent, to assess their interaction experience [7, 19-21]. Even though the administration of such questionnaires to a large number of participants can be considered free of desirability biases and practical information are gathered on user's preferences for such agents, such as their practical use, attractiveness, physical and emotional qualities it can be important to collect other information during the user-agent interaction. Previous studies showed that approach motivation and positive affect can be detected with EEG. Taken singularly, both questionnaires and EEG measures can have some limitations. However, combining information from both can results in collecting more reliable information about user's acceptance of virtual agents. For instance, several studies successfully categorized 'like' versus 'dislike' attitudes by assessing individual's frontal EEG asymmetry [50-54] showing that approach related motivation/positive affect is associated to relative left frontal activation and left-frontal LPPs. This can be a valuable information in user's acceptance studies about senior's preferences of virtual agents.

Neuromarketing researchers attempted to gain more insights into users' preferences and expectations by using the information derived from electrophysiological activities of motivation and emotion research and fuse these results by combining questionnaires and EEG measures [28, 56].

User acceptance research is one important aspect of improving technologies for assisting elderly. The main goal is to know whether user 'like' or 'dislike' the system and predict intentions to use it. Findings from EEG studies can be useful in users' preference predictions, and EEG recordings can give additional clues about participant's affective and motivational states. To summarise, by applying various techniques and combining different lines of research, we hope to obtain most effective measurements of user's acceptance of virtual agents contributing to the 'healthy ageing' policy of WHO by developing more useful and effective assistive technologies for the elderly.

In the light of previous findings, this paper proposes to investigate user acceptance of virtual agents among elderly. Participants will be right-handed Italian adults with no neurological and psychological disorders. Participants' EEGs will be recorded during the presentation of 12 virtual agents (differ in age, gender, physical appearance) and the VAAQ questionnaire will be used to assess pragmatic, hedonic, and attractive qualities of the proposed agents. In addition, frontal participants' EEG asymmetries during the interaction will be measured. Relationship between EEG-based approach motivation/positive affect and participants reported preferences will be investigated. It is hypothesized that participants' relative greater left frontal activation will be positively correlated to VAAQ scores of hedonic qualities-feeling, hedonic qualities-identity and attractiveness.

Acknowledgements: The research leading to these results has received funding from the European Union Horizon 2020 research and innovation programme under grant agreement N. 769872 (EMPATHIC) and N. 823907 (MENHIR) and from the project SIROBOTICS that received funding from Ministero dell'Istruzione, dell'Università, e della Ricerca (MIUR), PNR 2015-2020, Decreto Direttoriale 1735 del 13 luglio 2017.

REFERENCES

[1] J. Broekens, M. Heerink, H. Rosendal., "Assistive social robots in elderly care: a review." Gerontechnology, vol. 8(2), pp. 94-103, 2009.

[2] AS. Kaudinya, NSP. Atreyas, S. Srinivas, V. Kehav and NMR. Kumar, "Voice enabled home automation using amazon echo." Int. Res. J. Eng. Technol., vol. 4, pp. 682-684, 2017.

[3] A. Purington, JG. Taft, S. Sannon, NN. Bazarnova and SH. Taylor, "Alexa is my new BFF: social roles, user satisfaction, and personification of the amazon echo." Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems, ACM, 2017.

[4] S. Lesin, "Frederick' medical virtual assistant" Final project in Software Engineering Department, Afeka College for Engineering, Israel, 2016.

[5] M. Kramer, R. Yaghoubzadeh, S. Kopp and K. Pitsch, "A conversational virtual human as autonomous assistant for elderly and cognitively impaired users? Social acceptability and design considerations." Informatik angepasst an Mensch, Organisation und Umwelt, Germany, 2013.

[6] R. Yaghoubzadeh, M. Kramer, K. Pitsch and S. Kopp, "Virtual agents as daily assistants for elderly or cognitively impaired people." International Workshop on Intelligent Virtual Agents. Springer, Berlin, Heidelberg, pp. 79-91, 2013.

[7] A. Esposito et al., "Seniors' acceptance of virtual humanoid agents". In LNEE, Springer, 544, pp. 429-443, 2019.

[8] RK Moore, "A Bayesian explanation of the 'Uncanny Valley' effect…" Scientific Report, 2:864, pp.1-5, 2012.

[9] KF. MacDorman, H. Ishiguro, "The uncanny advantage of using androids…", Interaction Studies, vol. 3, pp. 297-337, 2006.

[10] YH. Wu, C. Fassert and AS. Rigaud, "Designing robots for the elderly", Archives of gerontology and geriatrics, vol. 1, pp. 121-126, 2012.

[11] F. Ferrari , MP. Paladino and J. Jetten, "Blurring human–machine distinctions:…", International Journal of Social Robotics, 8(2), pp. 287-302, 2016.

[12] H. Kamide, Y. Mae, K. Kawabe, S. Shigemi and T. Arai, "A psychological scale for general impressions of humanoids. In proc. IEEE ICRA, pp. 4030–4037, 2012.

[13] FD. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology." MIS Quarterly, pp. 319-340, 1989.

[14] V. Venkatesh, "A theoretical extension of the technology acceptance model: Four longitudinal field studies." Management Science vol. 42, pp. 186-204, 2000.

[15] V. Vanketesh, JYL. Thong and X.Xu,."Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology." MIS Quarterly, vol. 36, pp. 157-178, 2012.

[16] M. Heerink, B. Krose, V. Evers and B. Wielinga, "Assessing acceptance of assistive social agent technology by older adults: the almere model." International journal of social robotics, vol. 361-375, 2010.

[17] M. Hassenzahl, "The interplay of beauty, goodness, and usability in interactive products." Human-computer interaction vol. 19, pp. 319-349, 2004.

[18] M. Hassenzahl, "The thing and I: understanding the relationship between user and product." Funology, Springer, Dordrecht, pp. 31-42, 2003.

[19] MI. Torres et al, "The EMPATHIC project: Mid-term achivements." PETRA 19, Greece, 2019.

[20] A. Esposito et al, "Seniors' sensing of agents' personality from facial expressions." International Conference on Computers Helping People with Special Needs. Springer, Cham, 2018.

[21] A. Esposito et al, " Elders prefer female robots with a high degree of human likeness. " Unpublished.

[22] E. Harmon-Jones and PA. Gable, "On the role of asymmetric frontal cortical activity in approach and withdrawal motivation: An updated review of the evidence." Psychophysiology, vol. 55.1, 2018.

[23] EE. Smith et al, "Assessing and conceptualizing frontal EEG asymmetry: An updated primer on recording, processing, analyzing, and interpreting frontal alpha asymmetry." International Journal of Psychophysiology, vol. 111, pp. 98-114, 2017.

[24] M. Mustafa, S. Guthe, JP. Tauscher, M. Goesele and M. Magnor, "How Human Am I?: EEG-based Evaluation of Virtual Characters." Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems. ACM, 2017.

[25] S. Schindler et al. "Differential effects of face-realism and emotion on event-related brain potentials and their implications for the uncanny valley theory." Scientific reports, vol. 7, 2017.

[26] M. Cheetham, L. Wu, P. Pauli and L. Jancke Marcus, "Arousal, valence, and the uncanny valley: Psychophysiological and self-report findings." Frontiers in psychology, vol. 6, pp. 981, 2015.

[27] BA. Urgen et al, "Predictive coding and the Uncanny Valley hypothesis: Evidence from electrical brain activity." Cognition: A Bridge between Robotics and Interaction, *pp. 15-21, 2015.*

[28] A. Hakem et al, "More is Better: Using Machine Learning Techniques and Multiple EEG Metrics to Increase Preference Prediction Above and Beyond Traditional Measurements." bioRxiv, 2018.

[29] RJ. Davidson, "Anterior cerebral asymmetry and the nature of emotion." Brain and cognition, vol. 20.1, pp. 125-151, 1992.

[30] AJ. Tomarken et al, "Psychometric properties of resting anterior EEG asymmetry: Temporal stability and internal consistency." Psychophysiology, vol. 29.5, 1992.

[31] E. Harmon-Jones and JJ. Allen, "Anger and frontal brain activity: EEG asymmetry consistent with approach motivation despite negative affective valence." Journal of personality and social psychology, vol. 74.5, 1998.

[32] JA. Coan, and JJ. Allen, "Frontal EEG asymmetry and the behavioral activation and inhibition systems." Psychophysiology, vol. 40, 2003.

[33] AJ. Elliot, "Handbook of approach and avoidance motivation. " Psychology Press, 2013.

[34] R. Thibodeau, SR. Jorgensen and S. Kim, "Depression, anxiety, and resting frontal EEG asymmetry: a meta-analytic review." Journal of abnormal psychology, vol. 115.4, 2006.

[35] RJ. Davidson and NA. Fox, "Frontal brain asymmetry predicts infants' response to maternal separation." Journal of abnormal psychology, vol. 98.2, pp. 127, 1989.

[36] P. Ekman and RJ. Davidson, "Voluntary smiling changes regional brain activity." Psychological Science, vol. 4.5, pp. 342-345, 1993.

[37] PA. Gable and E. Harmon-Jones, "Approach-motivated positive affect reduces breadth of attention." Psychological Science, vol. 19.5, pp. 476-482, 2008.

[38] B. Schöne, J. Schomberg, T. Gruber, and M. Quirin, "Event-related frontal alpha asymmetries: electrophysiological correlates of approach motivation." Experimental brain research, vol. 234.2, pp. 559-567, 2016.

[39] G. Hajcak, A. Weinberg, A. MacNamara and D. Foti, "ERPs and the study of emotion." The Oxford handbook of event-related potential components, vol. 441, pp. 474, 2012.

[40] MM. Bradley, "Natural selective attention: Orienting and emotion." Psychophysiology, vol. 46.1, pp. 1-11, 2009.

[41] PJ. Lang and MM. Bradley, "Emotion and the motivational brain." Biological psychology, vol. 84.3, pp. 437-450, 2010.

[42] E. Harmon-Jones, AP. Gable, and CK. Peterson. "The role of asymmetric frontal cortical activity in emotion-related phenomena: A review and update." Biological psychology, vol. 84.3, pp.451-462,2010.

[43] PA. Gable, and BD. Poole, "Influence of trait behavioral inhibition and behavioral approach motivation systems on the LPP and frontal asymmetry to anger pictures." Social Cognitive and Affective Neuroscience, vol. 9.2, pp.182-190, 2012.

[44] PJ. Lang, "The emotion probe: studies of motivation and attention." American psychologist, vol. 50.5, pp. 372, 1995.

[45] V. Ferrari, M. Codispoti, R. Cardinale and MM. Bradley, "Directed and motivated attention during processing of natural scenes." Journal of cognitive neuroscience, vol. 20.10, pp.1753-1761, 2008.

[46] JK. Olofsson, S. Nordin, H. Sequeira, and J. Polich, "Affective picture processing: an integrative review of ERP findings." Biological psychology vol. 77.3, pp. 247-265, 2008.

[47] WA. Cunningham, SD. Espinet, CG. DeYoung and PD. Zelazo, "Attitudes to the right-and left: frontal ERP asymmetries associated with stimulus valence and processing goals." NeuroImage, vol. 28.4, pp. 827-834, 2005.

[48] L. Schilbach, et al, "Being with virtual others: Neural correlates of social interaction." Neuropsychologia, vol. 44.5, pp. 718-730, 2006.

[49] G. Aranyi, F. Pecune, F. Charles, C. Pelachaud and M. Cavazza, "Affective interaction with a virtual character through an fNIRS brain-computer interface." Frontiers in computational neuroscience, vol. 10, pp. 70, 2016.

[50] J. Teo, CL. Hou and J. Mountstephens, "Deep learning for EEG-Based preference classification." AIP Conference Proceedings. Vol. 1891. No. 1. AIP Publishing, 2017.

[51] A. Telpaz, R. Webb and DJ. Levy, "Using EEG to predict consumers' future choices." Journal of Marketing Research, vol. 52.4, pp.511-529, 2015.

[52] LH. Chew, J. Teo and J. Mountstephens, "Aesthetic preference recognition of 3D shapes using EEG." Cognitive neurodynamics, vol. 10.2, pp. 165-173, 2016.

[53] W. Kong, X. Zhao, S. Hu, G. Vecchiato and F. Babiloni, "Electronic evaluation for video commercials by impression index." Cognitive neurodynamics, vol. 7.6, pp. 531-535, 2013.

[54] N. Ravaja, O. Somervuori and M. Salminen, "Predicting purchase decision: The role of hemispheric asymmetry over the frontal cortex." Journal of Neuroscience, Psychology, and Economics, vol. 6.1, p. 1, 2013.

[55] WHO. What is Healthy Ageing? Available online: http://www.who.int/ageing/healthy-ageing/en/ (accessed on 4 December 2018).

[56] A. Hakim and DJ. Levy. "A gateway to consumers' minds: Achievements, caveats, and prospects of electroencephalography based prediction in neuromarketing." Wiley Interdisciplinary Reviews: Cognitive Science, vol. 10.2, 2019.

[57] J. Tasevski, M. Gnjatovic and B. Borovac. "Assessing the Children's Receptivity to the Robot MARKO. Acta Polytechnica Hungarica, vol 15.5, 47-66, 2018.

[58] K. Dautenhahn, C.L. Nehaniv, M.L. Walters, B. Robins, H. Kose-Bagci, N.A. Mirza, M. Blow: KASPAR –A Minimally Expressive Humanoid Robot for Human-Robot Interaction Research, Applied Bionics and Biomechanics6(3):369-397, 2009.

[59] J. Katona, T. Ujbanyi, G. Sziladi, A. Kovari, "Speed control of Festo Robotino mobile robot using NeuroSky MindWave EEG headset based brain-computer interface" 7th IEEE International Conference on Cognitive InfoCommunications (CogInfoCom). 000251-000256, 2016

[60] L. Izsó, "The significance of cognitive infocommunications in developing assistive technologies for people with non-standard cognitive characteristics: CogInfoCom for people with non-standard cognitive characteristic", 6th IEEE International Conference on Cognitive Infocommunications (CogInfoCom), 77-82, 2015.