Published by the Centre of Sociological Research, Poland

ISSN: 1795-6889

HUMAN TECHNOLOGY

Volume 17, Number 2, October 2021

Kristiina Korjonen-Kuusipuro
Adam Wojciechowski
Editors in Chief

https://ht.csr-pub.eu/

HUMAN TECHNOLOGY

Volume 17, Number 2, October 2021

DOI: https://doi.org/10.14254/1795-6889.2021.17-2

Contents

From the Publisher pp. 116–117
A New Home and The Bright Future for Human Technology
Yuriy Bilan

From the Editors in Chief pp. 118–125
Can Artificial Intelligence Become an Artist?
Kristiina Korjonen-Kuusipuro, Adam Wojciechowski

Original Articles

Does Telework Work? Gauging Challenges of Telecommuting to Adapt to a "New Normal" pp. 126–144
Agota Giedrė Raišienė, Violeta Rapuano, Tibor Dőry, Kristina Varkulevičiūtė

Virtual Reality Immersive Environments for Motor and Cognitive Training of Elderly People – A Scoping Review pp. 145–163
Adam Wojciechowski, Aneta Wiśniewska, Anna Pyszora, Magdalena Liberacka-Dwojak, Karolina Juszczyk

Applying Ethology to Design Human-Oriented Technology. An Experimental Study on the Signalling Role of the Labelling Effect in Technology's Empowerment pp. 164–189
Matthew E. Gladden, Artur Modliński

HUMAN TECHNOLOGY

ISSN: 1795-6889
https://ht.csr-pub.eu/

Submission: https://ht.csr-pub.eu/index.php/ht/about/submissions

Human Technology is an interdisciplinary, scholarly journal publishing innovative, peer-reviewed articles exploring the issues and challenges within human–technology interaction and the human role in all areas of ICT-infused societies.

Human Technology, published by the Centre of Sociological Research, Poland, is distributed without a charge online.

HUMAN TECHNOLOGY

ISSN: 1795-6889

https://ht.csr-pub.eu

Volume 17(2), October 2021, 116–117

From the Publisher

A NEW HOME AND THE BRIGHT FUTURE FOR *HUMAN TECHNOLOGY*

Yuriy Bilan
Director
Centre of Sociological Research
Szczecin, Poland

The ever-changing demands of the modern world dictate frequent adjustments necessary for any individual or entity that intends to stay relevant and competitive. And so it is with *Human Technology*: the publishers of the journal are pleased to announce that it too is evolving into a new iteration of its success as a scholarly journal while simultaneously maintaining its core principles and guidelines.

For 4 fruitful years at the Open Science Centre and 12 more with the Agora Center (which founded the journal), both independent institutions at the University of Jyväskylä, Finland, *Human Technology* has expanded its reach to readers all around the globe. With this issue, however, *Human Technology* begins a new era as a work of the Centre of Sociological Research (CSR) – a well-established platform aimed at promoting scientific discourse and research pursuits. This transfer of ownership will not disrupt the day-to-day operations of the journal; rather, it creates further opportunities for development and growth.

As the new publishers of *Human Technology*, we at CSR remain faithful to the long-standing ideals and traditions of scientific integrity and interdisciplinary collaboration that have been essential to its identity from the start. With the pandemic making its mark on multiple aspects of modern working life and, indeed, the very relationship between humans and technology, the versatility and all-encompassing nature of the subjects covered by the journal provide answers to and insights on the pressing demand for a multidisciplinary and thorough investigation of the myriad topics within this field.

Especially rapidly developing technologies involving artificial intelligence, affective computing, or human-computer collaboration are opening up new opportunities to make technology useful to humans and solve their problems. This will not succeed without the interdisciplinary cooperation of computer scientists, psychologists, physicians, or visionaries, for whom the Human Technology Journal provides a forum for sharing experiences.

DOI: https://doi.org/10.14254/1795-6889.2021.17-2.1

In taking in this publication, open-access since its inception, we at *Human Technology* pledge to keep providing quality research reports for scientists, students, and casual readers around the world. We concur with many contemporary academics that gatekeeping in the distribution of knowledge has no place in today's challenging times.

Further, from its first issue in 2005, *Human Technology* has been expanding the spectrum of its contributors and readers, reaching more countries and institutions with each new issue. The change of publisher will undoubtedly facilitate this process and allow the journal to gain further recognition as it taps into already-established networks associated with other journals published by CSR.

On that note, we at *Human Technology* look forward to invigorating the cooperation between and among Central European and Finnish tertiary-level institutions, scholars, and independent research centers, as well as attracting new partners from around Europe and beyond. Involving NGOs in the creative process, as is now a common *modus operandi*, represents one additional aspect of the journal's outreach activity that will receive increased attention in the near future.

This broadly recognized publication has been and continues to be indexed by the most reputable global databases. In turn, we share the gratitude expressed by the previous publishers of *Human Technology* toward the journal's contributors, editorial board members, reviewers, various partners, and, most importantly, the readers – all who have contributed to its success over the years. We at CSR, and particularly our new co-editors-in-chief and continuing and new editorial board members, eagerly look toward the future and the new frontiers that are sure to follow after this smooth transition. We thank you for your readership and hope you will remain an active participant in the continued growth and relevance of *Human Technology* in the interdisciplinary fields associated with the interaction of humans and technology.

Authors' Note

All correspondence should be addressed to
Assoc. prof. dr. hab. Yuriy Bilan
Director
Centre of Sociological Research, Szczecin
Faculty of Management
Rzeszow University of Technology, Rzeszow
Poland
y.bilan@prz.edu.pl
ORCID 0000-0003-0268-009X

Human Technology
ISSN 1795-6889
https://ht.csr-pub.eu

HUMAN TECHNOLOGY

ISSN: 1795-6889

https://ht.csr-pub.eu

Volume 17(2), October 2021, 118–125

From the Editors

CAN ARTIFICIAL INTELLIGENCE BECOME AN ARTIST?

Adam Wojciechowski
Lodz University of Technology,
Łódź, Poland

Kristiina Korjonen-Kuusipuro
University of Jyväskylä,
Jyväskylä, Finland

Abstract: *Modern visionaries claim supernatural abilities to artificial intelligence. Artificial intelligence has been attributed artistic skills, including those related to the visual arts. Is artificial intelligence a creator, or maybe it is the creators of algorithms who have to be creative, whose imagination is then transformed into works-of-art by a computer program? How are the rules that create aesthetic compositions created? Can we measure aesthetics? This article addresses the above questions by illustrating them with examples of visual arts created by intelligent algorithms.*

Keywords: *artificial intelligence, computational creativity, visual art.*

DOI: https://doi.org/10.14254/1795-6889.2021.17-2.2

INTRODUCTION

Let us consider whether a work of art made by a human and a computer are comparable? Do they have the same value? If one says no, this is direct evidence that the piece itself and the creation process affect the work's artistic value. Since nothing arises ex nihilo, it is essential to remember that most creative ideas originate from a historical-cultural background or some experience. If we have a creative idea ourselves, we very often attribute it to our ingenious invention or inspiration, thus rejecting a scientific explanation of the process by which the idea arose. Obviously, new ideas are not entirely new. We can say that our creative capabilities grow with experience and knowledge. The deeper it is, the greater the likelihood of discovering an original relationship underlying a new creative idea. Analogical to the laws of physics and theorems, musical pieces can be defined by a finite set of basic elements, suggesting creativity is an original way of solving problems based on memory records, looking for analogies, learning and inference. In this context, the process can be replicated by computers if both components and creation procedures are provided. It should be remembered that we have progressively improved artificial intelligence techniques that allow us to replicate such activities with increasing perfection. However, it is worth considering how Artificial Intelligence (AI) models the process of creativity, what components it uses, and how it describes the process itself.

Relations between computers and creativity are constantly being redefined with the rapid development of technologies. Artificial Intelligence has an especially significant influence on the creative process. Computers are no longer just a tool helping human creators but have become independent creative entities. In consequence, Computer Creativity has emerged as a new subfield of Artificial Intelligence. The mechanisms of computer creativity are still evolving, but logical systematics can be determined in it. At the same time, the question arises: Is computer creativity an attempt to imitate specific artistic patterns or exemplify the implicit rules that make up creative compositions? How to train Artificial Intelligence to exhibit behaviour that would be deemed creative in humans? What are the main challenges for computer creativity today?

Even though creative programs have proved their application in many fascinating areas, (like poetry (Lamb et al., 2017), storytelling (Gervás, 2009), humour (Ritchie, 2009)), this elaboration concentrates on visual art. The reason for discussing this artistic field lies in selected domain activity, and, by far, it is the one where the obtained results are the most impressive. The elaboration aims to understand the more in-depth methods involved in the "intelligent digital revolution of visual art".

COMPUTATIONAL CREATIVITY OF VISUAL ARTS

Artificial intelligence (AI) has moved on from an academic research topic to a global scientific and business incentive in recent decades. AI is not an exception, as many rapidly developing technologies are profoundly changing the prevailing paradigms in creative domains, attempting to fulfil the selected requirements of creative industries (Amato et al., 2019). AI has evolved from explicitly defined mathematical formulas (symbolic or logic-based) into implicit methods able to identify complex structures and patterns from datasets describing our environment and exploit them to make creative decisions or predictions. It relies on statistical learning from data and generalizing to unseen data.

It is important to note that the generation of aesthetic patterns dates to a period well before the recent rise of deep neural networks. Historically explored methods encompass Perlin noise-based concepts (Perlin, 2002) and L-systems' inspired biological patterns (Lindenmayer, 1974) to many others, (formalized stochastic or grammar-related routines). An inspiring complementarily studied methodology to generate plausible images and visual concepts are fractals (Barnsley et al., 1988). This practical, recently more widely used methodology for pattern generation is derived from mathematics. It uses algorithms for finding the roots of polynomials or algorithms in solving nonlinear equations. The field has even earned the name polynomialography. Its creator is considered to be Bahman Kalantari (Kalantari, 2005), who proposed methods for visualizing the zero places of complex polynomials in the form of fractal and non-fractal images, using the mathematical properties of the convergence of a sequence of function iterations. Picard, Mann, Ishikawa, Khan, Suantai, Karakaya and many other iterations are used among the popular functions for iterating approximate roots of a polynomial. Analogously, the formulas obtained from discrete dynamical systems theory are visually interesting. Gdawiec (2017), using various transformation functions to visualize the orbits of dynamical systems, has created a number of aesthetic patterns.

Figure 1. Aesthetic patterns obtained with polynominography (Gdawiec, 2017).

Further development of computer creativity, supported by deep neural networks, constituted a taxonomy of creativity. According to Boden (2004) there are three main types of creativity: combinational, exploratory and transformational.

Combinational creativity involves the deliberate or unconscious making of an unfamiliar combination of familiar ideas. Although this is technically one of the easiest methods (resulting in semantically abstract compositions), problems arise when evaluating the output - which should be valuable, have artistic value, and be human-relevant. Pure combinational rules seem to be insufficient to go beyond certain creativity limits.

Exploratory creativity is a type of creation that is structured by a conceptual space, specific style, genre or a scientific theory. In other words, the process of creation undergoes particular formation according to particular rules. Adopting a specific style, genre, or theory yields new and valuable results within determined rules. This approach can enable someone to see possibilities not perceived before. Machine learning plays a particularly important role in this field of creativity. The artificial intelligence methods accessing big sets of data learn from themselves and mimic previously processed patterns. AARON drawing system (Cohen, 1982) has become an example of this type of creativity. AARON is a robotic system, developed over many years by the artist and programmer Harold Cohen, which can pick up a paintbrush with its robotic arm and paint on canvas on its own. AARON draws human postures and plants, following previously learnt rules. Aaron's knowledge is acquired cumulatively. For example, when Aaron learns the concept of a plant, it can use it whenever it needs it, controlling principles of branching, aspects of thickness depending on size or the thickness of limbs.

One of Boden's remarkable sayings that "computers cannot do anything creative because they can only do what the program tells them to do is misleading since computers can do what its programs enable them to do" underlines the main bottleneck of computational creativity (Boden, 2009). In this context, it is essential to note that there are always algorithms whose creative effectiveness is at work in the background of programs.

Figure 2. *Two Friends with Potted Plant*, 1991. Oil on canvas by AARON, 60x84 inches. Photo: Becky Cohen. (source: *THE FURTHER EXPLOITS OF AARON, PAINTER,* Harold Cohen, 1994).

More recently, the potential of deep artificial networks has proved its usability in visual creativity acquired from a set of hand-made sketches. Ha et al. (2017) have proposed a Recurrent Neural Network to represent and reconstruct sketch drawings. Specifically, the authors managed to encode a vast set of hand-made sketches in the latent space of Sequence-to-Sequence Variational Autoencoder and decode them with autoregressive RNN. A crucial role in the sketch reconstruction process is played by the Gaussian Mixture Model, which encoded the distribution of ground truth data and helped semantically reconstruct the sketches.

Transformational creativity refers to the transformation of structured conceptual space. It is claimed to be the highest form of creativity, as it can generate new structures that could not have been observed before (Boden, 1998). While exploring unique aspects or new dimensions requires relatively small changes, transforming a more fundamental dimension or rule would result in possibly different and new structures within that space. Transformational creativity refers to radical changes. Thus, this high-level form of creativity is relatively difficult to implement in computer systems. Transformational creativity is difficult for computers to model as human associative memory and human values are difficult to express in computer forms. The result may not be interesting or valuable in human terms.

A well-grounded example of transformational creativity is DeepDream (Mordvitsev, 2015). It uses a Convolutional Neural Network (CNN) to find and enhance patterns in images via algorithmic pareidolia. The input images were deliberately over-processed through the convolutional pipeline, producing hallucinogenic visual art concepts. Initially, the DeepDream program was designed to understand how convolutional networks work, but its inherent ability to amplify certain features transformed it into an artistic tool. Sequential transformation of an image at different levels of abstraction amplifies elements seen by the network but not obvious in the original image.

Figure 3. Google DeepDream images (source: quora.com).

A resulting breakthrough in the visual arts is observed due to work on image style transfer using convolutional neural networks (Gatys et al., 2016). This work has inspired many new applications (i.e. Prisma[1], Artisto[2], Algorithmia[3]) of AI techniques for transferring styles between arbitrary images.

An interesting direction for transformative creativity is stimulated by the recently emerging Generative Adversarial Network (GAN) architectures (Goodfellow et al., 2014). The GAN network generates uniform distribution samples, and exploits discriminators, deciding whether they suitable for the real or generated image. Initially employed as a generator of images from a specific class, nowadays, they are used for many other applications. Notably, Elgammal et al. (2017) exploited GAN architecture to generate pastiches of selected images by introducing another style to the image. The solution's functionality is limited to style application but can also permute or combine image components to produce new pieces of art.

Besides pure image generation, intelligent editing can also be treated as a method for visual art creation. At the core of effective editing lies intelligent transformations (Gharbi et al., 2017) or retouching (Yan et al., 2014). However, algorithms based on artificial intelligence in transformations or retouching have to strongly rely on semantic analysis of the content and many image transformation examples. Efficient separation of content and style information guarantee higher reliability of the algorithm output. Artificial intelligence focusing on image inpainting is able to reconstruct damaged or missing parts of an image so that the modifications cannot be perceived. Based on a deep convolutional GAN network, such a method was proposed by (Yeh et al., 2016) to replace missing parts of an image with meaningful content. A missing eye, for instance, can be generated and placed in the correct position. While the algorithms are perfectly acceptable at completing or retouching objects of known and typical appearance, such as the human face, perfection in this area is strongly desired and requires further development to generate generic scenes effectively.

[1] https://prisma-ai.com/
[2] https://artisto.my.com/
[3] https://demos.algorithmia.com/deep-style/

CHALLENGES

Despite the many spectacular successes in computer creation with artificial intelligence, some art recipients point out a number of shortcomings. While the generation of art images, sometimes abstract, seems possible and aesthetically interesting, the generation of photorealistic images using AI is still challenging. Just a between image style transfer seems to be relatively advanced and available as a technique for artists. Due to the infinite number of patterns and rules describing referential environments, photorealistic computer creativity has become an unachieved goal for generative art.

Some creators expect to be able to create visual art based on a semantic description. However, generating graphics from a description presents another challenge. Underpinning the solution to this problem is semantic analysis and transcription between many different forms of data description. While there are encouraging successes in individual domains (phrase analysis, ontologies, or dictionary-based description generation), a valuable and comprehensive solution in computer visual art with the potential for another breakthrough in computer creativity is still out of reach.

Although automatic recognition of image content is emerging (mainly due to the development of algorithms for semantic segmentation and classification of an increasing number of object classes), this task, in general, is still quite challenging. Techniques of automated image content analysis also influence possible creativity schemes. The effectiveness of component recomposition or hierarchical decomposition of inherent structures, describing the analyzed environment, defines further challenges and opportunities in developing artificial intelligence for the visual arts. Efficient retrieval of graph-based image structural decomposition will result in algorithms that build more reliable artistic creations.

The final issue, one which is, on the one hand, challenging but also an essential part of the creation process, is the evaluation of computer creativity. By evaluating the design, we can improve the algorithms and methods to address increasingly complex tasks. Assessment of creative quality is rarely reported in the literature, mainly due to their subjective nature. One group of authors postulating the determinants of creativity was Maher et al. (2012). These authors, supporting other researchers, claim that we can talk about the creativity of work when it has the characteristics of novelty, is valuable and arouses surprise. A more formal approach to measuring the level of creativity was presented by Fuge et al. (2013). By introducing submodular functions, the authors introduce measures of creativity in computer-based design synthesis systems with reference to models (if definable) or based on human judgement-based metrics.

However, current considerations in the literature indicate that the well-known Turing test, in which subjects are asked to judge whether a human or a computer has created selected designs, is perhaps the most widely used referential form of assessing the provenance of visual art and its quality. In contrast, other non-referential, objective measures have yet to be legitimized.

Reactions to visual art made by AI have varied from competitor to collaborator, from positive to more sceptical (Zeilinger, 2021). Both this and the above-mentioned need to know whether the artist is human or machine, is probably due to the idea that creativity is still considered something very human. This is also connected to the relational and diverse nature of the material world. We need to rethink our understanding of how the social and the physical have material effects in an ever-changing world that is in a continuous state of 'coming into being' (Barad, 2007; Haraway, 2004). When it comes to AI and visual arts, we need to rethink agency as being something more than just human subjectivities and intentionalities. Feminist scholar Karen Barad (2007) sees agency as intra-action, an entanglement of human and non-human forces. She stresses the way agency involves the refiguring of material-discursive possibilities and accountability of bodily production. Materialities, including digital materialities, take various forms, and because of the blurred nature of human-material relations, materiality is 'an ongoing discursive construct and material formation that is co-constituted about its material environment' (Höppner & Urban, 2018). Furthermore, this is also connected to our ideas of knowing. A shift from *knowing about* towards *knowing with* the world has emerged, which stresses that the relations we have and produce with our surroundings are not only modes of being but simultaneously of knowing (Barad, 2007; Rautio, 2014).

REFERENCES

Amato, G., Behrmann, M., Bimbot, F., Caramiaux, B., Falchi, F., Garcia, A., ... & Vincent, E. (2019). AI in the media and creative industries. *arXiv preprint arXiv:1905.04175*.

Barad, K. (2007) *Meeting the unverse half way. Quantum Physics and the entanglement of matter and meaning*. Durham & London: Duke University Press.

Barnsley, M. F., Devaney, R. L., Mandelbrot, B. B., Peitgen, H. O., Saupe, D., Voss, R. F., ... & McGuire, M. (1988). *The science of fractal images* (pp. xiv+-312). New York: Springer.

Boden, M. A. (2009). Computer models of creativity. *AI Magazine*, *30*(3), 23.

Boden, M. A. (2004). *The creative mind: Myths and mechanisms*. Routledge.

Boden, M. A. (1998). Creativity and artificial intelligence. *Artificial intelligence*, *103*(1-2), 347-356.

Cohen, H. (1982). How to make a drawing. In *talk given to the Science Colloquium, National Bureau of Standards, Washington DC* (Vol.17).

Ahmed Elgammal, Bingchen Liu, Mohamed Elhoseiny, Marian Mazzone. CAN: Creative Adversarial Networks Generating "Art" by Learning About Styles and Deviating from Style Norms

Fuge, M., Stroud, J., & Agogino, A. (2013, August). Automatically inferring metrics for design creativity. In *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (Vol. 55928, p. V005T06A010). American Society of Mechanical Engineers.

Leon A. Gatys, Alexander S. Ecker, Matthias Bethge. Image Style Transfer Using Convolutional Neural Networks. ECCV 2016

Gervás, P. (2009). Computational approaches to storytelling and creativity. *AI Magazine*, *30*(3), 49-49.

Gdawiec, K. (2013, September). Aesthetic Patterns from the Perturbed Orbits of Discrete Dynamical Systems. In *IFIP International Conference on Computer Information Systems and Industrial Management* (pp. 358-366), Springer, Berlin, Heidelberg.

Gdawiec, K., Kotarski, W., & Lisowska, A. (2015, February). Polynomiography based on the nonstandard Newton-like root finding methods. In *Abstract and Applied Analysis* (Vol. 2015), Hindawi.

Gdawiec, K. (2017). Switching processes in polynomiography. *Nonlinear Dynamics*, *87*(4), 2235-2249.

Michaël Gharbi, Jiawen Chen, Jonathan T. Barron, Samuel W. Hasinoff, Frédo Durand, Deep Bilateral Learning for Real-Time Image Enhancement, ArXiv:1707.02880v2

J. Goodfellow, Jean Pouget-Abadie, Mehdi Mirza, Bing Xu, David Warde-Farley, Sherjil Ozair, Aaron Courville, and Yoshua Bengio. 2014. Generative adversarial nets. In Proceedings of the 27th International Conference on Neural Information Processing Systems - Volume 2 (NIPS'14)

Ha, D., & Eck, D. (2017). A neural representation of sketch drawings. *arXiv preprint arXiv:1704.03477*.

Haraway, D. (2004). *The Haraway Reader*. London: Routledge.

Höppner, G., Urban, M. (2018). Where and How Do Ageing Processes Take Place in Everyday Life? Answers from a New Materialist Perspective. *Frontiers in Sociology,* 3(7). https://doi.org/10.3389/fsoc.2018.00007.

Kalantari, B. (2005). Polynomiography: from the fundamental theorem of Algebra to art. *Leonardo*, *38*(3), 233-238.

Lamb, C., Brown, D. G., & Clarke, C. L. (2017). A taxonomy of generative poetry techniques. *Journal of Mathematics and the Arts*, *11*(3), 159-179.

Lindenmayer A. (1974) L-systems in their biological context. *Proceedings of conference on "Biologically motivated automata theory"*, McLean, Virginia.

Maher, M. L., & Fisher, D. H. (2012). Using AI to evaluate creative designs. In *DS 73-1 Proceedings of the 2nd International Conference on Design Creativity Volume 1*.

Perlin, K. (2002, July). Improving noise. In *Proceedings of the 29th annual conference on Computer graphics and interactive techniques* (pp. 681-682).

Rautio, P. (2014). Mingling and Imitating in Producing Spaces for Knowing and Being: Insights From a Finnish Study of Child–Matter Intra-Action. *Childhood*, 21(4), 461–474.

Ritchie, G. (2009). Can computers create humor? *AI Magazine*, *30*(3), 71-71.

Zhicheng Yan, Hao Zhang, Baoyuan Wang, Sylvain Paris, Yizhou Yu, Automatic Photo Adjustment Using Deep Neural Networks, arXiv:1412.7725v2

Raymond A. Yeh, Chen Chen, Teck Yian Lim, Alexander G. Schwing, Mark Hasegawa-Johnson, Minh N. Do, Semantic Image Inpainting with Deep Generative Models, arXiv:1607.07539

Zeilinger, M. (2021). *Tactical Entanglements: AI Art, Creative Agency, and the Limits of Intellectual Property*, Lüneburg, Meson Press.

Authors' Note

All correspondence should be addressed to
Adam Wojciechowski
Lodz University of Technology,
Łódź, Poland
adam.wojciechowski@p.lodz.pl
ORCID 0000-0003-3786-7225

Human Technology
ISSN 1795-6889
https://ht.csr-pub.eu

HUMAN TECHNOLOGY

ISSN: 1795-6889

https://ht.csr-pub.eu Volume 17(2), October 2021, 126-144

DOES TELEWORK WORK? GAUGING CHALLENGES OF TELECOMMUTING TO ADAPT TO A "NEW NORMAL"

Agota Giedrė Raišienė
Klaipėda University
Lithuania;
Széchenyi István University
Hungary

Violeta Rapuano
Mykolas Romeris University
Lithuania

Tibor Dőry
Széchenyi István University
Hungary

Kristina Varkulevičiūtė
Telia Company
Lithuania

Abstract: *The paper aims to contribute to a deeper understanding of organisation management while telecommuting. With exploratory factor analysis (EFA), we define the specific set of telework organising efficiency characteristics. We determined the number of factors with Kaiser Eigenvalues rule as well as Cattel's scree criterion. We conducted the study in Lithuania, the country with a low percentage of teleworkers until organisations have been urged to properly implement their performance to remote means after the COVID-19 quarantine was announced. This paper reveals that the fundamental challenges of teleworking are the feedback issues related to working accomplishment, especially to the task and process overload, and individual self-organisation ability. Moreover, the flexibility of work organisation represents a unique characteristic of telework, and managers should cooperate more effectively with teleworkers to keep them motivated.*

Keywords: *telework, organisation management, human resource management, exploratory factor analysis.*

DOI: https://doi.org/10.14254/1795-6889.2021.17-2.3

INTRODUCTION

The implementation of restrictive measures to combat the COVID-19 pandemic (Bonacini et al., 2021) has led to far-reaching socio-economic consequences and shifts worldwide, such as labour market shocks in financial well-being (Botha et al., 2021; Milani, 2021) and acceleration of the processes of work digitization that have taken place so far (McDonald et al., 2020) to mention but a few. The recent concerns about the increase in workers' migration in western countries (Jędrzejowska-Schiffauer, Schiffauer, 2017) faced with the pandemic have turned to another challenge – migration constraints (Bite et al., 2020; Oliinyk et al., 2021). Interestingly, employers have been considering reducing the adverse effects of business travel for quite a while already, hoping that distant meetings could improve the balance between costs and expenses (Faulconbridge et al., 2020). The relocation of workers and the global restrictions of movement makes it possible to evaluate the new working and business conditions in many ways. If mobility would not be constrained, we could talk about an experiment in which thousands of workers joined digital nomads (Aroles et al., 2020). On the other hand, it is the work efficiency of nomads and similar issues addressed in the scientific literature over the last decade that allows the knowledge of teleworkers' challenges.

It is telecommuting that enabled companies to adapt to such crises as the COVID-19 outbreak. Telework has also become a key policy instrument used by governments worldwide to minimise the pandemic's spread (Reuschke, Felstead, 2020). An organization's capability to switch to telework has become the main resilience factor in the pandemic's context. Many countries have to deal with specific problems independently, and in this light, the importance of cultural features is re-emerging (Kaasa, 2019). Until the pandemics, telework was differently popular in various countries. The tightening competition in the world economy, requiring more flexible work arrangements (Karamanis, Gogos, 2020; Whiting, Symon, 2020) made telework more relevant. Trends in labour intensification are also reflected in emerging activities, some of which are becoming new digital professions (Kristal, 2019). In Europe, the percentage of people who have worked from home at least in 2018 ranged from 0-10% in Romania, and Macedonia, 11-20% in Lithuania, Bulgaria, and Portugal, to 51-60% in Sweden, Denmark, and Netherland (Reuschke, Felstead, 2020). Before the pandemic, telework was considered useful due to the potential for business cost savings and ways for the organisation to be faster and more agile (Großer, Baumöl, 2017; Morrison-Smith, Ruiz, 2020). Research conducted in the US shows that the employment rates of highly skilled workers, the so-called white-collar workers, are significantly worse after the economic crises (Lopez, Phillips, 2019). However, in the current pandemic, more positive consequences can be expected, as intellectual work was exceptionally well possible through teleworking.

Working conditions, including teleworking, has also been used to motivate employees by enabling them to improve their work-life balance (Klopotek, 2017; Bulková & Masárová, 2017; Gálvez et al., 2011; Peters et al., 2008). However, the global shift of workers to work from home has changed the situation. Working from home for a year has finally begun to bring new aspects of telework to light. So far, they are not unambiguously clear.

There is a lack of knowledge to evaluate and adapt to new conditions (Bloom et al., 2020; McKibbin & Roshen, 2020; Chang & Velasco, 2020). Organisations that have not yet applied to telecommuting have implemented telework without knowing how to do it effectively. Professional organisations also faced surprises, difficulties, and a lack of reliable knowledge (Micko, 2020; Neeley, 2020). While researchers of telework have so far highlighted the challenges of communication, collaboration and application of technology in cyberspace (e.g., Snellman, 2014), the scale of telecommuting challenges has expanded in the face of a pandemic. Updated research-based recommendations have become vital for organisations in times of “new normal” (Bonacini, Gallo, & Scicchitano, 2021).

With regard to this relevance thus, our paper aims to contribute to a deeper understanding of organisation management while telecommuting. Using exploratory factor analysis (EFA), the paper defines the sets of characteristics of telework organisation's efficiency. The identified factors of telework efficiency based on the research results also serve from a practical point of view: conducting telework research in organisations enables managers to detail the most significant aspects of teleworking.

The paper's remaining paragraphs are as follows: theoretical substantiation of the research construct, the research methods presentation, and the review of the research results. The paper ends with conclusions and recommendations.

The Theoretical Background of Telecommuting

Jack Nilles (1975) first used the term telecommuting. Variety of telework terms are found in the scientific literature: *teleworking, home-based work, working from home, home-based telework, homeworking, telecommuting, virtual office, virtual work, e-work, flexiplace, flexible work* (Nakrošienė & Butkevičienė, 2016; Brinzea & Secara, 2017). The literature also finds such telework methods as *part-time work*, *flexi-time*, *annualised hours, compressed workweeks, hours distributed differently, telework* (Brinzea & Secara, 2017). Regardless of the term chosen, these authors analogously describe telework. It is working from home or elsewhere using technology and communicating with the manager, colleagues and clients remotely (European Social Partners, 2006).

When examining the differences between teleworking and office work, researchers consider both methods' advantages and disadvantages by grouping them. We can also see that researchers most often analyse the challenges for the individual and the organisation (e.g., Allen et al., 2015; Nakrošienė, Butkevičienė, 2016; Rose, 2019; Talwar, 2020; Kraft, 2019; Micko, 2020; Neeley, 2020). However, it can be seen that some other researchers are not limited to the discussion at the employee and organisational level. Nyaanga (2012) notes the benefits of teleworking for society and business and that teleworking has a positive effect at the macro level. It reduces energy consumption and traffic congestion and thus contributes to environmental protection and safeguarding of resources. When speaking about business, the author emphasizes better talent retention, more significant organisational commitment and loyalty, and overall company productivity. In general, the productivity of employees is particularly highlighted in telework research reports. Based on research data, Rose (2019) states that 77 per cent of employees feel more productive when working from home. Other authors note that teleworking in an organisation helps attract and keep highly qualified professionals (Raghuram et al. 2019). Mahler (2012) emphasises that teleworking positively affects savings in office, labour, commuting costs, and work continuity under adverse conditions.

However, it must be acknowledged that telework is not suitable for all professions and not for all individuals. Telework pays off for people with self-discipline and time management skills (Morrison-Smith., Ruiz, 2020) and can create obstacles for other employees. Telework requires advanced ICT literacy, which has become one of the "must-have" skills for all generations. Millennials were valued for IT adaptation even before the pandemic and, in general, this generation has been constructed as a 'challenge' to poor management with respect to other generations (Williams, 2019). Currently, personal leadership skills have become important for all generations of teleworkers. The previous studies showed that ICT use might be significantly altering job conditions in terms of work intensification, which, in turn, contributes to employee strain and distress (Chesley, 2014). The willingness to telework is also an important aspect to analyse. The study of Cortés-Pérez et al. (2020) has shown that cultural traits are significant when determining remote work's willingness.

Furthermore, the blurred work-family boundaries when trying to fill “work” and “home” domain roles simultaneously can lead employees to experience role conflict, stress, and reduced work motivation (Rofcanin, Anand, 2020). Sewell and Taskin (2015) have come to interesting conclusions in terms of the autonomy of teleworkers. According to the authors, in contrast to the many optimistic predictions, virtual working does not lead to the “emergence of a truly autonomous and self-determining worker“. It is more about the reordering of control through the reshaping of norms. Accordingly, teleworking requires highly flexible and diverse leaders (McCann & Kohntopp, 2019; Even, 2020). Managers' empathy and emotional intelligence become the key qualities when organizing work remotely. A study conducted during the 2020 global COVID-19 crisis showed that companies' success was accompanied by leaders who could motivate and engage staff when working from home (Talwar, 2020).

Another significant telework challenge is mutual trust between employees and managers. When employees' physical activity is not visible, even in evidence of employee productivity, managers have difficulties in controlling (Kraft, 2019). Teleworking makes it challenging to manage employees' workloads; both too low and too high workload are a concern for managers (Taskin, Bridoux, 2010). Besides, teleworkers experience reduced opportunities to change work, with many workers feeling constrained to improve and fully participate in the labour market (Dunn, 2020). In general, telework organisation requires special preparation from both the organisation's strategic level managers and the specialists' direct managers. Managers face difficulties in combining leadership and management functions as it is necessary to manage both performances and create a reliable and collegial work environment. Leaders need to help supply the proper infrastructure for the job, take an interest in the employees' psychological state, agree on the communication means, frequencies, and rules and make sure team members always feel aware of what is happening (Neeley, 2020).

Finally, recent research shows that the authors emphasize the communication aspects and the changed approach to communication when discussing telework's challenges because of the pandemic experience. According to Micko (2020), the essential lesson of unplanned telework is overcommunication. Leaders must use all tools to communicate with staff and customers to inform them about the current situation, explain why one or another decision is made, and the next step. Organizing virtual teams work requires more emailing and sharing than the traditional way of working (Neeley, 2020).

Previous studies on telework note that virtual work creates new workplace dynamics complexities, making communication and coordination more challenging despite sophisticated information and communication technologies (Mahler, 2012). Additional research (e.g., Gottfredson, 2020; Kraft, 2019) confirms that there is less feedback, communication and collaboration when working remotely despite the confirmed positive impact of distance technologies on working and business results (Braja & Gemzik-Salwach, 2020; Potjanajaruwit & Girdwichai, 2019). According to Rose (2019, p. 23), even the physical absence of several key team members in meetings leads to group miscommunication, misunderstandings, and more errors in the later implementation of meeting decisions. Accordingly, Sandberg (2020) argues that one of the most significant losses when starting work remotely is the absence of spontaneous conversations. According to the author, a successful long-distance relationship may require more conscious communication, such as quick daily calls, text messages, or online chats. Recent research shows that leaders in the face of COVID-19 had to rapidly implement both technological and managerial innovations to cooperate with teleworkers effectively. For example, Sandberg (2020) introduces a practice when managers ask employees to prepare a daily feedback letter. In such a way, managers become better informed about what employees live for, respond quickly to employees' work-related needs, and solve emerging problems.

Summarizing the reviewed articles, such advantages and disadvantages of telework can be identified (see Table 1).

Table 1. Telework Contradictions.

Advantages of Teleworking	Disadvantages of Telework
Freedom of time planning	Longer working hours
Autonomy in decision making	Lower visibility, noticeability
Time saved on commuting	Blurred boundaries between work and personal life
Possibility to balance work and personal life	More difficult conditions for career development
Possibility to limit unnecessary interaction, no distraction from colleagues	Lack of face-to-face interaction
Reduced workplace maintenance costs	Personal costs for the home-office
More comfort for employees	Challenges for managers
Higher commitment	More complex communication

Theoretical analysis of telework challenges enabled identifying teleworking efficiency and organisational effectiveness that require greater managerial attention and thoughtful decisions. It should be noted that some of the factors found, such as higher commitment, time planning, or decision-making autonomy, are related to an individual's abilities that decide the individual's final performance and even the group to which he or she belongs. The relevant factors of telework efficiency identified based on empirical analysis study results distinguish the latter from the challenges' general context. Research methodology and results are presented further.

METHODOLOGY

A previous study on telework (Raišienė et al., 2020), based on correlation analysis, allowed us to reveal the evaluation of telework in different sociodemographic groups of respondents. In this study, we examined telework from a distinct perspective. The research's focal point is to find the most positive and most negative generalized aspects of telework. EFA analysis application on our data set allows us to reveal the underlying structure of telework characteristics by grouping them into more generalized groups. As a result of doing this, we can identify the most significant telework factors in terms of motivation and demotivation for telework, as well as to determine the required skills for telework.

Instruments. Based on the analysis of scientific publications on teleworking (Table 1), we formed a questionnaire for evaluating teleworking efficiency. The survey was composed of three segments of items: 1) advantages of teleworking. This segment's questions were meant to evaluate what motivates best for telecommuting (e.g., “Possibility to choose worktime”, “Possibility to limit unnecessary interaction (non-work-related chat, coffee breaks, etc.)”; 2) disadvantages of teleworking. These questions were given in order to identify the factors harming telework efficiency (e.g., “Working overtime due to the manager's inability to estimate workload”, “Blurred boundaries between work and personal life”); 3) required skills for teleworking. This segment of questions was given to find out what skills are required for efficient telecommuting (e.g., “Good time management skills”, “Strong personal responsibility for one's work (results, deadlines, etc.)”). Participants were also asked to supply socio-demographic information: their age group, gender, education and a field of activity.

The survey participants were offered a closed type of questionnaire and asked to express their opinion by five-point Likert scale ranging from 1 (Not important at all) to 5 (absolutely essential). To verify the reliability of the questionnaire, Cronbach's alpha coefficient was invoked. Cronbach alpha for advantages of teleworking scale was 0,791, for disadvantages of teleworking scale were 0,946 and required for teleworking – 0,798.

Participants and procedure. Data collection took place within a few very first weeks of quarantine in Lithuania. Based on the official statistics (Statistical indicators, 2020), there are 1359097 employed persons in Lithuania. 41 % (N=557230) of all employed persons worked from home during Covid-19 (Baltijos tyrimai, 2020). Thus, the sample size, calculated based on Paniotto's formula (for 95% reliability and 5% error), was 384. 436 properly completed questionnaires were received.

Data were collected via a web-based survey, which took approximately 15 min. on average to complete. The data collected was stored in data files and later downloaded into SPSS statistical software for analysis. All participants were informed about the purpose of the study. Participation was voluntary, and the respondents were assured of the confidentiality of their response.

The sample comprised of 32,6 % (N=142) men and 67,4 % (N=294) women (Table 1). Concerning age distribution, there were 4 age groups: 64 % (N=249) of participants aged 17-37, 33 % (N=144) of participants aged 38-56 and 3 % (N=13) of 57-77 years old age group. Nearly 22 % (N=94) of the respondents had secondary education, 38 % (N=167) held bachelor's degree, 34 % (N=149) had master's degree and 6 % (N=26) had doctor's degree. In terms of activity fields, the vast majority of the participants worked in the field of services and intellectual outputs (N=198), 7,6 % (N=33) worked in the field of production and trade, 23,6 % (N=103) of the participants worked in the field of management and administration and 11,7 % (N=51) worked in the field of health, education and social services.

Data analysis. To find and examine the underlying dimensions of the three instruments, factor analysis was used. This statistical method is used to reduce many variables into fewer numbers of factors. The grouping is done by calculating the correlation between variables. One part includes variables that strongly correlate with each other but weakly correlate or do not correlate with different variables, which form other components. Exploratory factor analysis explores the possible underlying structure of a set of interrelated variables without imposing preconceived structure on the outcomes. This method is applied when the number of components is unknown and what variables form them and if the variables are linearly related in general.

There are several requirements for a dataset to be suitable for factor analysis. Firstly, the data should be related to each other, e.g., and they should correlate. This assumption can be checked with the first correlation matrix. The sampling adequacy for factor analysis is verified using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity. These two methods conclude a minimal standard, mandatory before conducting a factorial analysis.

Secondly, KMO measures sampling adequacy for each variable in the model and the complete model need to be verified. The statistic is the measure of the proportion of variance among variables that might be common variance. KMO returns values between 0 and 1. A value close to 1 shows that patterns of correlations are compact, and so factor analysis should yield distinct and reliable factors. Kaiser (1974) put the following values on the results: 0,00-0,49 unacceptable, 0,50 to 0,59 miserable, 0,60 to 0,69 mediocre, 0,70 to 0,79 middling, 0,80 to 0,89 meritorious and 0,90 to 1,00 marvellous.

Moreover, it is also mandatory to verify whether there are statistically significantly correlating variable pairs saw at all. Bartlett's test of sphericity reveals this. This test compares an observed correlation matrix to the identity matrix. The null hypothesis of the test is that the variables are orthogonal, i.e., not correlated. The alternative hypothesis is that the variables are not orthogonal, i.e., they are correlated enough. Factor analysis has no meaning when the p-value of Barlett's test is higher or equal to the selected significance level.

Furthermore, it was checked whether significant differences between distinguished factors exist in terms of gender, education and field of activity of respondents. Mann - Whitney U test was applied in order to look for dependences on gender. Dunn-Bonferroni post hoc method following a significant Kruskal-Wallis test was used to determine the differences of resulting factors among groups of education and activity field.

Table 2. KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0,813
Bartlett's Test of Sphericity	Approx. Chi-Square	989,345
	Df	36
	Sig.	0,000

In total, 9 components were distinguished during the factor analysis. Table 3 lists the eigenvalues associated with each component (factor) before extraction, after extraction and after rotation and shows each evaluated component's dispersion. The *Total* column gives the eigenvalue or variance in the original variables accounted for by each component. The *% of variance* column shows the ratio, expressed as a percentage, of the variance accounted for by each component to the total variance in all the variables. The *Cumulative %* column gives the percentage of variance accounted for by the first *n* components. There are as many components as variables for the initial solution, and in correlation analysis, the sum of the eigenvalues equals the number of components.

The eigenvalue of the first factor is 3,463. As this value is higher than 1,0, it means that the factor explains 3,463 times more dispersion than a separate variable. In percent values, the first factor explains 3,463/9 = 0,3482 or 34,82% dispersion. If a factor's eigenvalue is less than 1, it explains less dispersion than a separate variable. In order to decide what number of factors should be retained, Kaiser's criterion was invoked. Kaiser's criterion is suggested to investigate factors the eigenvalues of which are higher or equal to 1. In addition to the eigenvalue criterion, the scree plot was visually inspected to decide how many factors should be retained. In our case, a two-factor structure (see Table 3) has been captured from the instrument. Cumulative variance explained by these two factors was 53,305%. The constituted factor model is applicable if stays not less than 50 % of the initial variable dispersion (Field, 2009); accordingly, we can state that our factor model is appropriate.

Table 3. Total Variance Explained.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1.	3,463	38,482	38,482	3,463	38,482	38,482	2,775	30,831	30,831
2.	1,334	14,823	53,305	1,334	14,823	53,305	2,023	22,474	53,305
3.	0,814	9,044	62,349						
4.	0,753	8,363	70,713						
5.	0,695	7,719	78,431						
6.	0,598	6,640	85,072						
7.	0,515	5,717	90,789						
8.	0,498	5,401	96,189						
9.	0,343	3,811	100,000						

As can be seen in Table 4, Factor 1 has 5 items. The percentage of total variance explained by the first factor was 38,48 %. This factor was named *Flexibility of work organisation*. The 2 factor comprises 4 items and explains 14,82 % of the total variance. It was labelled *Social independence*. After the scale items were identified using factor analysis, the factors' internal consistency was determined by computing an Alpha coefficient (Cronbach). The test evaluates whether all questions of the scale reflect the investigated value and allow to specify the number of questions needed in the scale. Cronbach's alpha reliability coefficient ranges typically between 0 and 1. The closer the Cronbach alpha coefficient is to 1,0, the greater the scale items' internal consistency. There are different reports about the acceptable values of alpha, ranging from 0,70 to 0,95 (Nunnally, Bernstein, 1994). If the scale is only used for statistical analysis (as in our particular case), the authors suggest that Cronbach's alpha may be lower than 0,7, but it should nonetheless be around 0,5. In our case, the Cronbach's alpha of factor 1 is 0,796, which can be considered as good and 0,663 for factor 2, which is acceptable.

Table 4. The Results of Teleworking Advantages Factor (Fa) Analysis.

		L	%	α
Fa_1. The Flexibility of Work Organisation				
1.	Possibility to choose worktime	0,775	38,482	0,796
2.	Possibility to independently organize work	0,772		
3.	Possibility to balance work and personal life	0,732		
4.	Possibility to work individually	0,673		
5.	Possibility to choose workplace	0,660		
Fa_2. Social Independence				
1.	Possibility to avoid formal dress code and appearance-related requirements at the workplace	0,787	14,823	0,663
2.	Possibility to limit unnecessary interaction (non-work-related chat, coffee breaks, etc.)	0,705		
3.	Possibility to better keep up with the selected wellness program	0,684		
4.	Time saved on commuting	0,544		

Next, we examined the underlying factors of the telework disadvantages scale. The Kaiser–Meyer–Olkin measure verified the sampling adequacy for the analysis; a KMO value of 0,942 was obtained (Table 5). This shows that the sample adequacy for explored factor analysis is marvellous. The Bartlett's test of sphericity χ^2 (406) = 6702,498, p<0,001 was significant, showing that the data are adequate to conduct a factor analysis.

Table 5. KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		**0,942**
Bartlett's Test of Sphericity	Approx. Chi-Square	6702,498
	Df	406
	Sig.	0,000

Items with eigenvalues greater than 1 were kept in the factor. A four-factor structure (see Table 6) has been captured from the instrument. The first eigenvalue of 11,682 corresponds to the first factor associated with 40,282 % of the original data variance. The next eigenvalues are 1,945, 1,661 and 1,308, respectively, corresponding to 57,226 % of the original data variance.

Table 6. Total Variance Explained.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1.	11,682	40,282	40,282	11,682	40,282	40,282	4,557	15,713	15,713
2.	1,945	6,707	46,988	1,945	6,707	46,988	4,185	14,431	30,144
3.	1,661	5,726	52,714	1,661	5,726	52,714	4,020	13,862	44,066
4.	1,308	4,511	57,226	1,308	4,511	57,226	3,834	13,219	57,226
5.	0,968	3,338	60,563						
6.	0,946	3,263	63,826						
7.	0,842	2,903	66,729						
...	...	...	...						
28.	0,231	0,797	99,280						
29.	0,209	0,720	100,00						

10 items were loaded onto factor 1 and were labelled as *Feedback issues related to work accomplishment* (Table 7). The percentage of total variance explained by the first factor was 40,282. The second factor has 6 items, and it explains 6,707 % of the total variance. Factor 2 was named *Communication-related challenges.* The third factor comprised 7 items labelled as *Challenges related to interpersonal relationships*, and it explained 5,726 % of the total variance. Finally, the fourth factor, named *Challenges associated with a non-standard work environment*, explained 4,511 % of the total variance. It comprised of 5 items.

What is more, the questionnaire scale internal consistency was evaluated using Cronbach's alpha coefficient. The Cronbach's alpha values of telework disadvantages factor scale fluctuate from 0,833 to 0,900. It can be stated that the internal consistency of the scales is particularly good.

Finally, we explored the dimensions of the scale of the qualities required for teleworking. An examination of the Kaiser-Meyer Olkin measure (0,830) of sampling adequacy suggested that sample adequacy for explored factor analysis is meritorious (Table 8). The Bartlett's test of sphericity χ^2 (21) = 896,994 was significant ($p<0,001$), showing that the data are adequate to conduct a factor analysis.

Table 7. The Results of Teleworking Disadvantages Factor (Fd) Analysis.

		L	%	α
Fd_1. Feedback issues related to work accomplishment				
1.	Exaggerated expectations of the manager/employer, without taking into consideration the actual workload	0,732	40,282	0,900
2.	Working overtime due to the manager's inability to estimate workload	0,666		
3.	Doubts regarding evaluation: will the managers notice and adequately appreciate my results	0,657		
4.	Information overload	0,629		
5.	Being under the impression that other people finish their tasks and enjoy life at home while I continue working all the time	0,572		
6.	Communication overloads	0,538		
7.	Career restrictions due to limited possibilities to demonstrate exceptional skills or extraordinary work results	0,537		
8.	Complicated access to work-related information	0,505		
Fd_2. Communication-related challenges				
1.	Time-consuming asynchronous communication (text messages and discussions)	0,727	6,707	0,865
2.	Tensions due to the distribution of attention between work tasks and intense communication	0,702		
3.	Extended on-line meetings	0,699		
4.	Extended decision-making time	0,686		
5.	When telecommuting the team becomes focused on the communication rather than the tasks	0,660		
6.	Difficulties in identifying the start and end of several simultaneously implemented tasks	0,622		
Fd_3. Challenges related to interpersonal relationships				
1.	Lack of face-to-face interaction with colleagues	0,723	5,726	0,853
2.	Lack of team spirit, the "we" feeling	0,683		
3.	Constraints on the possibilities to build mutual trust	0,672		
4.	Lack of face-to-face interaction with the manager	0,663		
5.	Lack of mutual trust between employees and their managers	0,604		
6.	Communication problems with other employees	0,559		
7.	Lack of feedback	0,527		
Fd_4. Challenges related to the non-standard work environment				
1.	Challenges related to self-organisation and following of work routine	0,742	4,511	0,833
2.	Distractions when teleworking by other household members	0,726		
3.	Blurred boundaries between work and personal life	0,720		
4.	Self-motivation related challenges	0,671		
5.	Lack of inspirational work atmosphere	0,552		
6.	Lack of understanding on the part of family members (do not consider telecommuting as "serious" work)	0,531		

Table 8. KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0,830
Bartlett's Test of Sphericity	Approx. Chi-Square	896,994
	Df	21
	Sig.	0,000

Next, the factor analysis extracted two factors since the eigenvalue greater than 1 (Table 9). The first eigenvalue of 3,302 corresponds to the first factor associated with 47,167 % of the original data variance. The second eigenvalue of 1,001 corresponds to the second factor associated with 14,306 % of the original data variance. To sum up, the cumulative percentage of the total variance explained by the two extracted factors was 61,473 %.

Table 9. Total Variance Explained.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1.	3,302	47,167	47,167	3,302	47,167	47,167	2,457	35,101	35,101
2.	1,001	14,306	61,473	1,001	14,306	61,473	1,846	26,372	61,473
3.	0,763	10,907	72,381						
4.	0,606	8,655	81,035						
5.	0,546	7,798	88,833						
6.	0,443	6,324	95,157						
7.	0,339	4,843	100,000						

As can be seen in Table 10, Factor 1 contains four items, which were named *Self-organisation and independent working skills*. The reliability coefficient Cronbach alpha of this factor is 0,764, which can be considered as good. Factor 2 was labelled *Personal leadership skills*, and it comprises three items. The Cronbach alpha of Factor 2 is acceptable – 0,645.

Table 10. The Results of The Required Qualities for Teleworking Factor (Fq) Analysis.

		L	%	α
Fq_1. Self-organisation and independent working skills				
1.	Ability to work independently	0,842	47,167	0,764
2.	Good time management skills	0,821		
3.	Strong personal responsibility for one's work (results, deadlines, etc.)	0,729		
4.	Digital literacy	0,550		
Fq_2. Personal leadership skills				
1.	Personal leadership	0,825	14,306	0,645
2.	Good communication skills	0,775		
3.	Ability to engage and maintain a commitment to the organisation	0,615		

It can be noted that there is a significant difference between the importance of telework skills in Factor 1. Working independently and good time management skills were considered more important than strong personal responsibility for one's work and digital literacy. Even though Factor 2 was of lesser importance and explained only 14,3 % of the total variance, it still indicates that personal leadership is noteworthy when managing teleworkers.

Finally, dependences between resulting factors and social-economic variables were verified. Firstly, we explored whether distinguished sets of teleworking characteristics depend on gender.

Table 11. Factor Dependences on Gender.

Factor	Gender	N	Mean Rank	Mann-Whitney U	p
Fd_1. Feedback issues related to work accomplishment	Male	142	236,85	18268,500	0,034
	Female	294	209,64		
Fd_2. Communication-related challenges	Male	142	244,76	17144,500	0,002
	Female	294	205,81		
Fd_4. Challenges related to the non-standard work environment	Male	142	238,02	18102,500	0,024
	Female	294	209,07		
Fq_1. Self-organisation and independent working skills	Male	142	186,63	16349,000	0,000
	Female	294	233,89		
Fq_2. Personal leadership skills	Male	142	188,00	16543,000	0,000
	Female	294	233,23		

There were no differences in the evaluation of the factors of teleworking advantages between men and women ($p > 0,05$). However, the analysis showed that men significantly more than women emphasize negative aspects of teleworking. They experience more feedback issues related to work accomplishment ($p = 0,034$), communication-related challenges ($p = 0,002$), and challenges related to the non-standard work environment ($p = 0,024$). In terms of required qualities for teleworking, women significantly more than men payed attention to self-organisation and independent working skills ($p < 0,001$) as well as personal leadership skills ($p < 0,001$).

Next, we examined the resulting factors depending on the education of the respondents (Table 12). The results of the test demonstrated significant differences in the factors of the required qualities for teleworking in terms of education of the respondents.

Table 12. Factor Dependences on Education.

Factor	Education Group	N	Mean Rank	χ^2	P
Fq_1. Self-organisation and independent working skills	Secondary school	94	159,53	28,596	0,000
	Bachelor's degree	167	232,51		
	Master's degree	149	232,78		
	Doctor's degree	26	259,87		
Fq_2. Personal leadership skills	Secondary school	94	172,69	20,259	0,000
	Bachelor's degree	167	236,35		
	Master's degree	149	233,34		
	Doctor's degree	26	184,40		

We found that respondents holding secondary school degree value less self-organization and independent working skills as compared to the respondents having a bachelor ($p < 0,001$), master ($p < 0,001$), and doctor degree ($p = 0,001$). Furthermore, they attach less importance to personal leadership skills when teleworking compared to the respondents holding bachelor ($p = 0,001$), and master degree ($p < 0,001$).

Analysing distinguished factors in terms of the field of activity (Table 13), we found that respondents working in the field of management and administration as well those working in health, education and social services attach more importance to self-organisation and independent working skills than respondents working in the field of services and intellectual outputs ($p = 0,026$; $p = 0,022$).

Table 13. Factor Dependences on the Field of Activity.

Factor	Field of Activity	N	Mean Rank	χ^2	p
Fq_1. Self-organisation and independent working skills	Services and intellectual outputs	198	203,83	31,558	0,000
	Production and trade	33	243,70		
	Management and administration	103	249,01		
	Health, education, and social services	51	263,04		
	Other	51	152,98		
Fq_2. Personal leadership skills	Services and intellectual outputs	198	207,68	16,222	0,003
	Production and trade	33	215,05		
	Management and administration	103	252,07		
	Health, education, and social services	51	237,59		
	Other	51	175,84		

Finally, respondents working in the management and administration field assigned more importance to personal leadership skills ($p = 0,033$) as the qualities required to remote worker, compared to those working in the field of services and intellectual outputs.

DISCUSSION

Comparing the theoretical analysis of telework in terms of organisation management and empirical research conducted during mass work from home can indicate that most focus points remained unchanged. Still, new nuances and specific changes emerged in the attitudes of teleworkers towards working conditions.

This paper shows that employees consider such factors as "Flexibility of work organisation" and "Social independence" to be positive when working from home. Similar to the findings of earlier research, our study confirmed the importance of autonomous decision-making for teleworkers. In this regard, teleworkers value the possibility of choosing worktime, independently organising work, balancing work and personal life, and choosing the workplace. However, it was surprising that one of the principal factors is that employees value working individually. In the literature, the limited opportunity to work together in teams is emphasized as a drawback of telework (e.g., Eikenberry, Wayne, 2018; Even, 2020). Thus, our study results indirectly suggest that keeping team collaboration requires more effort from managers and raises whether the teamwork is not overestimated if the opportunity to work individually is seen as an advantage of teleworking rather than a disadvantage. This question becomes less rhetorical when we see that the factor "Social independence" is characterized by the possibility of not following formal requirements for appearance and routine, taking care of personal health, avoiding informal communication with co-workers and saving time from communication in general. However, we cannot make generalized conclusions about communication avoidance without further research. Our study showed that employees were not satisfied with relatives at home during the working day as well – respondents felt distracted by them. Besides, the fact that the survey was conducted in different circumstances, during the quarantine due to the pandemic, should not be overlooked. The intensity of communication in the respondents' environment was unusually increased.

On the other hand, the research results show that communication with managers stays relevant for the employees, i.e., factor "Feedback issues related to work accomplishment". Employees wanted to be noticed and valued by managers, and they were concerned whether managers did not directly see them will not affect performance evaluation and career. Less frequent feedback between managers and employees was found as a drawback of telecommuting.

The research results also showed that "Communication-related challenges" are crucial for telecommuting in all circumstances. However, our study participants did not highlight the lack of communication and miscommunication, nor the limitations of nonverbal expressions, which was mentioned in the literature; instead, they emphasized the increased time needed for telecommuting, i.e., prolonged meetings and excessive focus on the communication process itself, leaving the desired result blurred in the background.

In terms of telecommuting contradictions, it may seem inconsistent that respondents marked such factors as individual communication and restriction of social contacts as advantages of teleworking. In contrast, respondents equally assessed the lack of social connections as a disadvantage of telework. However, it should be noted that the employees did not lack communication as such. Instead, there was not enough team spirit or "we-feeling", which was challenging to ensure while working from home. Respondents also noted that working from home makes it more difficult to achieve mutual trust with managers. It can be said that teleworkers lack what organisational culture brings when working in an office – organisational identity and a sense of belonging.

As a disadvantage of telework, respondents emphasized the non-standard work environment. Employees are distracted by the home environment, work is interfering with personal life, and there is a lack of inspiration for work. It is important to note separately that factors found in the study, such as "Self-organisation and independent working skills" and "Personal leadership skills" fall into the area of employees' abilities. Research has shown that telework requires an individual's ability to work independently, time planning skills, and personal responsibility for work outcomes. Besides, a teleworker needs to have personal leadership skills, practical communication skills, and the ability to engage and commit to the organisation. As can be seen, the manager's role should be specified, and the decision-making power should be shared in a teleworking environment.

CONCLUSIONS

This paper highlights the sets of telework advantages and disadvantages and group the personal qualities needed for a modern teleworker. Finally, teleworking has its specificities in terms of human resource management. It is working in a different context, created primarily by the social environment of the individual employee. For a teleworker, the significance of the organisation's requirements decreases and his or her own needs in terms of job performance and personal assessment become sharper. Thus, managers need to rethink their working methods when working with telecommuters. The identified factors enable an assessment of telework in the organisation in a structured and targeted manner and consider telework organisation improvement. The results revealed that the work organisation's flexibility could be considered the major advantage of teleworking. Such factors as the possibility of choosing worktime, independently organising work or opportunity to balance work and personal life are the key motivators for the work from home. Besides, our study has shown the significance of feedback issues related to working accomplishment when telecommuting. In this concern, the manager's exaggerated expectations, working overtime due to the manager's inability to estimate workload and doubts regarding evaluation were indicated as the most demotivating factors. This is an essential finding for organisation managers to rethink and implement innovative managerial methods to cooperate with teleworkers and keep them motivated effectively. The identified groups of telework factors serve as the guidelines for organizations (e.g., large-scale organizations situated in different countries) that are not ready to deal with their employees telework-related issues. Rather, on the contrary, we emphasize that these are the guidelines that should be followed by employers seeking to create conditions for productive work.

REFERENCES

Allen, T.D., Golden, T.D., & Shockley, K.M. (2015). How Effective Is Telecommuting? Assessing the Status of Our Scientific Findings, *Psychological Science in the Public Science, 16*(2), 40-68.

Aroles, G., Granter, E., & de Vaujany, F.X. (2020). 'Becoming mainstream': the professionalisation and corporatisation of digital nomadism, *New Technology*, *Work and Employment, 35*(1), 114-129.

Baltijos tyrimai, 2020 Baltic Research, (2020). https://www.vz.lt/nekilnojamasis-turtas-statyba/2020/04/27/apklausa-jaunesni-darbuotojai-nori-grizti-dirbti-i-biura

Bite, P., Konczosné Szombathelyi, M., & Vasa, L. (2020). The Concept of Labour Migration from the Perspective of Central and Eastern Europe. *Economics and Sociology, 13*(1), 197-216. doi: 10.14254/2071-789X.2020/13-1/13

Bloom, N., Bunn, P., Mizen, P., Smietanka, P., & Thwaites, G. (2020). The impact of Covid-19 on businesses' expectations: evidence from the Decision Maker Panel, Bank of England, Quarterly Bulletin 2020 Q3.

Bonacini, L., Gallo, G. & Scicchitano, S. (2021). Working from home and income inequality: risks of a 'new normal' with COVID-19. *Journal of Population Economics, 34,* 303–360. https://doi.org/10.1007/s00148-020-00800-7.

Botha, F., de New, J.P., de New, S.C., Ribar, D.C., & Salamanca, N. (2021). Implications of COVID-19 labour market shocks for inequality in financial wellbeing. *Journal of Population Economics,* https://doi.org/10.1007/s00148-020-00821-2

Braja, M., & Gemzik-Salwach, A. (2020). Competitiveness of high-tech exports in the EU countries. *Journal of International Studies, 13*(1), 359-372. doi:10.14254/2071-8330.2020/13-1/23

Brinzea, V.-M., Secara. C.G., 2017. The Telework, a Flexible Way to Work in a Changing Workplace. *Scientific Bulletin - Economic Sciences / Buletin Stiintific - Seria Stiinte Economice, 16*(3), 104–12.

Chang, R., & Velasco, A. (2020). Economic Policy Incentives to Preserve Lives and Livelihoods, National Bureau of Economic Research, Working Paper Series No. 27020. doi: 10.3386/w27020.

Chesley, N. (2014). Information and communication technology use, work intensification and employee strain and distress, *Work, Employment and Society, 28*(4), 589-610.

Cortés-Pérez, H.D., Escobar-Sierra, M., & Galindo-Monsalve, R. (2020). Influence of Lifestyle and Cultural Traits on the Willingness to Telework: A Case Study in the Aburrá Valley, Medellín, Colombia, Global Business Review, 1-17.

Dunn, M. (2020). Making gigs work: digital platforms, job quality and worker motivations, *New Technology, Work and Employment*, *35*(2), 232-249.

Eikenberry, K., & Wayne T. (2018). The Long-Distance Leader: Rules for Remarkable Remote Leadership. Oakland, California: Berrett-Koehler Publishers.

Even, A. (2020). The Evolution of Work: Best Practices for Avoiding Social and Organizational Isolation in Telework Employees https://doi.org/10.2139/ssrn.3543122

Faulconbridge, J., Jones, I., Marsden, G., & Anable, J. (2020). Work, ICT and travel in multinational corporations: the synthetic work mobility situation, *New Technology, Work and Employment*, *35*(2), 195-214.

Field, A. (2009). Discovering statistics using SPSS. London: SAGE Publications.

Gálvez, A., Martínez, M., & Pérez, C. (2011). Telework and Work-Life Balance: Some Dimensions for Organisational Change. *Journal of Workplace Rights, 16,* 273-297.

Gottfredson, R. (2020). COVID-19 And Remote Work: What Is Required of Leaders and Employees? *Leadership Excellence, 37*(4), 9.

Großer, B., & Baumöl, U. (2017). Why virtual teams work – State of the art. Procedia Computer Science, 121, 297-305. doi: 10.1016/j.procs.2017.11.041

Jędrzejowska-Schiffauer, I., & Schiffauer, P. (2017). New constraints on mobility in Europe: Policy response to European crises or constitutional ambiguity? *Journal of International Studies, 10*(3), 9-23.

Kaasa, A. (2019). Determinants of individual-level social capital: Culture and personal values. *Journal of International Studies, 12*(1), 9-32. doi:10.14254/2071-8330.2019/12-1/1

Kaiser, H.F. (1974). An index of factorial simplicity. *Psychometrika* 39, 31–36. https://doi.org/10.1007/BF02291575

Karamanis, K., & Gogos, C. (2020). The impact of flexible working at firm level. Evidence from Greek labor market. *Journal of International Studies*, *13*(2), 9-24.

Klopotek, M. (2017). The advantages and disadvantages of remote working from the perspective of young employees. *Organisation and Management, 40*(4), 39–49.

Kraft, M.H.G. (2019). How to Lead with Digital Media Effectively? A Literature-Based Analysis of Media in an E-Leadership Context. *Journal of Economic Development, Environment & People, 8*(4), 42–53.

Kristal, T. 2019. Computerization and the Decline of American Unions: Is Computerization Class-Biased? *Work and Occupations*, *46*(4), 371-410.

Lietuvos ekonomikos statistiniai rodikliai. Darbuotojų apdraustųjų skaičius, (2020). Statistical indicators of the Lithuania's economy. Number of Insured Employees, 2020. https://rekvizitai.vz.lt/statistika/apdraustieji-darbuotojai/

Lopez, S.H., & Phillips, L.A. (2019). Unemployed: White-Collar Job Searching After the Great Recession. *Work and Occupations*, *46*(4), 470-510.

Mahler, J. (2012). The Telework Divide: Managerial and Personnel Challenges of Telework. *Review of Public Personnel Administration*, *32*(4), 407-418.

McCann, J., & Kohntopp, T. (2019). Virtual Leadership in Organizations: Potential Competitive Advantage? *SAM Advanced Management Journal*, *84*(3).

McDonald, P., Williams, P., & Mayes, R. (2020). Means of Control in the Organization of Digitally Intermediated Care Work, *Work, Employment and Society,* 1-9.

McKibbin, W., & Roshen F. (2020). The Global Macroeconomic Impacts of COVID-19: Seven Scenarios, CAMA Working Paper No. 19/2020. http://dx.doi.org/10.2139/ssrn.3547729

Micko, M. (2020). Overcommunication: A Leadership Lesson from the Crisis. *Carrier Management, 7*(4), 55–56.

Milani, F. (2021). COVID-19 outbreak, social response, and early economic effects: a global VAR analysis of cross-country interdependencies. *Journal of Population Economics, 34*, 223–252.

Morrison-Smith, S., & Ruiz, J. (2020). Challenges and barriers in virtual teams: a literature review. SN Appl. Sci. 2, 1096. https://doi.org/10.1007/s42452-020-2801-5

Nakrošienė, A., & Butkevičienė E. (2016). Nuotolinis darbas Lietuvoje: samprata, privalumai ir iššūkiai darbuotojams. *Filosofija, Sociologija, 27*(4), 364–72.

Neeley, T. (2020). 15 Questions About Remote Work, Answered. Harvard Business Review Digital Articles, March, 2–7.

Nilles, J.M. (1975). Telecommunications and Organizational Decentralization. *IEEE Transactions on Communications, COM-23*(10), 1142-1147.

Nunnally, J., & Bernstein, L. (2010). Psychometric theory. New York: Mc Graw-Hill Higher Education.

Nyaanga, S.G. (2012). The Impact of Telecommuting Intensity on Employee Perception Outcomes: Job Satisfaction, Productivity, and Organizational Commitment. ProQuest LLC, Ph.D. Dissertation, Stevens Institute of Technology.

Oliinyk, O., Bilan, Y., Mishchuk, H., Akimov, O. & Vasa, L. (2021). The Impact of Migration of Highly Skilled Workers on The Country's Competitiveness and Economic Growth. *Montenegrin Journal of Economics, 17*(3), 7-19. doi: 10.14254/1800-5845/2021.17-3.1

Peters, P., Wetzels, C., & Tijdens, K. (2008). Telework: Timesaving or Time-Consuming? An Investigation into Actual Working Hours. *Journal of Interdisciplinary Economics*, *19*(4), 421-442. doi:10.1177/02601079X08001900407

Potjanajaruwit, P., & Girdwichai, L. (2019). Creative innovation of startup businesses in Thailand 4.0 era. *Journal of International Studies*, *12*(3), 222-231. doi:10.14254/2071-8330.2019/12-3/18

Raghuram, S.N. Hill, J.S., Gibbs, J.L., & Maruping, L.M. (2019). Virtual Work: Bridging Research Clusters. *ANNALS*, *13*, 308–341. https://doi.org/10.5465/annals.2017.0020

Raišienė, A.G., Rapuano, V., Varkulevičiūtė, K., & Stachová, K. (2020). Working from Home—Who Is Happy? A Survey of Lithuania's Employees during the COVID-19 Quarantine Period. *Sustainability*, *12*, 5332. https://doi.org/10.3390/su12135332

Reuschke, D., & Felstead, A. (2020). Changing workplace geographies in the COVID-19 crisis. *Dialogues in Human Geography*, *10*(2), 208-212.

Rofcanin, Y., & Anand, S. (2020). Human Relations virtual special issue: Flexible Work Practices and Work-Family Domain. *Human Relations*, *73*(8), 1182-1185.

Rose, S. (2019). Remote Work Is Sticking Around. *Workforce Solutions Review*, *10*(4), 22–25.

Sandberg, J. (2020). Best Practices for Managing Remote and Global Teams. *International Educator*, 1059-4221.

Sewell, G., & Taskin, L. (2015). Out of Sight, Out of Mind in a New World of Work? *Autonomy, Control, and Spatiotemporal Scaling in Telework, 36*(11), 1507-1529.

Snellman, C.L. (2014). Virtual Teams: Opportunities and Challenges for e-Leaders. *Procedia - Social and Behavioral Sciences*, *110*, 1251-1261. https://doi.org/10.1016/j.sbspro.2013.12.972.

Talwar, R. (2020). Future Insight. *Training Journal*, *6*(April).

Taskin, L., & Bridoux, F. (2010). Telework: a challenge to knowledge transfer inorganizations. The *International Journal of Human Resource Management*, *21*(13), 2503-2520. https://doi.org/10.1080/09585192.2010.516600

Whiting, R., & Symon, G. (2019). Digi-Housekeeping: The Invisible Work of Flexibility. *Work, Employment and Society*, *34*(6), 1079-1096.

Williams, G. (2019). Management Millennialism: Designing the New Generation of Employee. *Work, Employment and Society*, *34*(3), 371-387.

Živčicová, E., Bulková, K., & Masárová, T. (2017). Comparison of the Selected Indicators of Work Life Balance in European Union Countries. *Economics and Sociology*, *10*(1), 222-231. https://doi.org/10.14254/2071-789X.2017/10-1/16

Authors' Note

All correspondence should be addressed to
Agota Giedrė Raišienė
Klaipėda University, Lithuania
Széchenyi István University, Hungary
agotagiedre.raisiene@ku.lt,
agotagiedre@gmail.com

Human Technology
ISSN 1795-6889
https://ht.csr-pub.eu

HUMAN TECHNOLOGY

ISSN: 1795-6889

https://ht.csr-pub.eu Volume 17(2), October 2021, 145–163

VIRTUAL REALITY IMMERSIVE ENVIRONMENTS FOR MOTOR AND COGNITIVE TRAINING OF ELDERLY PEOPLE – A SCOPING REVIEW

Adam Wojciechowski
Institute of Information Technology, Lodz University of Technology
Poland

Aneta Wiśniewska
Interdisciplinary Doctoral School at the Lodz University of Technology
Poland

Anna Pyszora
Faculty of Health Sciences Collegium Medicum in Bydgoszcz, Nicolaus Copernicus University in Toruń
Poland

Magdalena Liberacka-Dwojak
Faculty of Psychology
Kazimierz Wielki University, Bydgoszcz
Poland

Karolina Juszczyk
Faculty of Psychology
Kazimierz Wielki University, Bydgoszcz
Poland

Abstract: *The contemporary development of immersive virtual reality interfaces holds untapped potential for the rehabilitation and motor-cognitive training of older adults. Despite the parallel development of gamification methods involving users in interactive experiences and the dynamic development of sensors and techniques for tracking human bio-physiological activities, the cognitive and motor experiments for the elderly, proposed in the literature, are relatively schematic, have limited modalities, and fail to exploit the capabilities of contemporary VR infrastructure. Moreover, the proposed state-of-the-art solutions are arbitrary and their authors usually do not go beyond a simple compilation of popular computer games supported with alternative displays. There is a shortage of exploration of new scenarios combining contemporary immersive virtual environments and the results of experiments on cognitive and motor stimulation of elderly people in an acceptable way for seniors. This paper provides a critical analysis of the contemporary state-of-the-art, followed by constructive insights into the potential of technology and provides inspiration and proposals for solutions that represent a new quality in cognitive-motor rehabilitation.*

DOI: https://doi.org/10.14254/1795-6889.2021.17-2.4

Keywords: *virtual environments, seniors, cognitive training, motor training, immersive virtual reality, scoping review.*

INTRODUCTION

Ageing society and the accompanying problems of both cognitive and motor skill deterioration can be mitigated by emerging computer technologies. Three-dimensional interactive visualizations providing immersive experiences can stimulate the elderly beyond their limited experience with new technologies. Modern virtual environments (VE) have modernized the clinical approach to rehabilitation practises; virtual reality (VR) systems have proved their therapeutic potential regarding falls prevention and balance rehabilitation and finally, virtual reality training can stimulate functional activities and promote social interaction when collectively performed and encourage the elderly to adhere to their rehabilitation programme (Amorim et al., 2019, Taipale & Hänninen, 2018). On the other hand, virtual reality systems for the elderly are still designed with limited consideration of the expectations and limitations of the target users. Interactive virtual systems are rarely built based on a critical and systematic analysis of seniors' expectations but rather based on an arbitrarily selected subset of older adults' cognitive and/or motor deficits and the alleged computer simulations' corresponding functionalities. There is a shortage of studies comparing the effectiveness of various virtual reality systems in cognitive and motor rehabilitation. Papers evaluating the effectiveness of a particular system on a predetermined group of target users are most common. Among the solutions described, although not very numerous, non-immersive systems predominate. Virtual immersive systems based on popular and widely available virtual head-mounted displays and dedicated controllers are extremely rare, especially in the field of motor training. Concurrently, the technological awareness of the older generation, especially in large aglomerations of highly developed countries, continues to grow (Jouhki, 2019). The state-of-the-art derived conclusions are therefore the direct inspiration for writing the following elaboration which aims to elicit a set of design recommendations that combine the potential of contemporary immersive virtual reality interfaces with the growing expectations of an ageing society. Indeed, the development of effective and ubiquitous computer-based systems, both for cognitive and motor training, determines wellbeing and independence in late adulthood.

On the other hand, VR interactive systems and their interfaces' functionalities as well as simulation scenarios, when carelessly designed or implemented, directly affect system usability and may evoke some side effects. The implementation of interactive VR systems, especially for the elderly, should be carried out primarily with safety in mind, then taking into account the needs and elderly person's possibilities as well as the gradation of the occurrence of involutional changes. Additionally, the issues of digital skills of older people and ability to use the interface self-sufficiently and effectively should be respected.

Virtual reality systems could be a promising solution for cognitive and physical debilities in the elderly, especially through combining cognitive and physical activities, along with entertainment. Immersive VR allows the creation of flexible, personalized, and safe multimodal training, using naturalistic and real-time settings. VR systems for the elderly are increasingly reported to be highly effective, achieving better effects than traditional activities (Bauer & Andringa, 2019).

The main contribution of the provided study is an in-depth analysis of state-of-the-art VR systems. The study inclines towards immersive solutions in terms of both the psychologically motivated expectations and motor limitations of older adults as well as the IT limitations of contemporary technology. The study was developed by an interdisciplinary team consisting of computer scientists, psychologists and physiotherapists who, in addition to their academic background, have extensive practical experience focused on seniors. The review concludes with a set of recommendations that find a compromise between user expectations and the capabilities of existing VR technologies.

PSYCHOMOTOR EXPECTATIONS OF OLDER PEOPLE RESULTING FROM THE LIMITATIONS OF LATE ADULTHOOD

Cognitive functioning, defined as multiple mental abilities, such as attention, memory, executive cognitive function, and language, are crucial for independent living, communicating, or integrating sensory information. Cognitive abilities often deteriorate throughout life, contributing to several limitations. The most perceptible changes in cognition are declines in performance on attentional tasks, such as selective or divided attention. Healthy adults encounter such difficulties progressively with age. Episodic or sensory memory remains stable with normal ageing, but there are relevant changes in learning new abilities, short-term memory, working memory (relevant for holding information temporarily), or even prospective memory (remembering to perform intended action in the future). Furthermore, executive functioning also declines throughout one's life span. Decision-making, problem-solving, planning, or multitasking become challenging. The decline in cognitive functioning is mostly associated with age-related changes in brain structure and function, like neuronal dysfunction or neuronal loss (Murman, 2015).

The elderly are not a homogeneous group and typically suffer from various disease entities or disorders, including cognitive functioning. At the same time, the dynamic development of information technologies, including virtual reality, provides a number of opportunities that allow them to positively affect the comfort of life and the rehabilitation of physical and cognitive deficits as well as training the corresponding skills. Using the achievements of modern technology, however, requires searching for such a range of stimuli and modalities that, on the one hand, allow the individualization of user interfaces and, on the other hand, maximize the experience. Additionally, a balance must be found between individualizing needs and the universality of the solution, which may limit the usability of the systems designed. In the case of usual or successful ageing, we can talk about the management of the ageing process, which determines both independence and quality of life.

The main priority of successful management of ageing is enabling older people to be healthy, active and autonomous for as long as possible. Accordingly, functional decline is one of the key issues to be managed (WHO, 2015). These key issues might be supported, among others, by different assistive health technologies or medical devices, but their effectiveness depends on accessibility and familiarity with the exploited technologies. Virtual environment systems are examples of emerging assistive technologies supported by medical devices in ageing and disabilities treatment. Virtual environments interventions have several determinants of successful cognitive and motor rehabilitation. These are repetitive practice, feedback about performance, multimodal stimulation and a secure and ecologically valid environment (Bahil, 2011).

At the same time, the use of technology is usually hindered by several groups of barriers (Wildenbos et al., 2018). Among the most important are cognitive limitations and motivational limitations. The former include working memory, spatial cognition, attention, language and reasoning, whereas the latter include self-efficacy, self-confidence, integration in daily life. Physical limitations relate to motor speed, flexibility, hand-eye coordination, strength and the perception of the efficiency of the fundamental sense organs (sight, hearing and touch). These limitations increase the risk of falls (Duray & Genç, 2017). In addition, motor activity itself may be affected by cognitive disorders, creating limitations related to learning, remembering, concentration, effectiveness and passing individual tasks. In the case of older people, where depression is one of the great geriatric problems, motivation and well-being might be activated through modern technology. In the case of elderly people, the implementation of scenarios related to relaxation and stress reduction should also be taken into account (Riches et al., 2021).

It must be noted that VR system usability and the resulting impact is determined by users' presence in VE (Riva & Waterworth, 2014). This is only partly related to the realism of the environment but also to the interaction flow performed by means of controlled actions satisfying users' intentions. This in turn can be facilitated by an easy-to-learn interface, understandable serious game structure and engaging storytelling (Triberti & Riva, 2016).

Cognitive-Related Limitations

Cognitive impairment and psychomotor deterioration among older adults make it difficult to experience modern interactive virtual simulations. Dynamic changeability of surrounding environments and non-intuitive methods of environment visualizations control seems to be one of the most crucial bottlenecks hindering the perception of virtual worlds.

Among others, a set of requirements should concern user interface appearance and functionality. Adequate colour contrast and pictographic metaphors rather than textual information, implying legibility and clarity of instructions, constitute another group of regulations recommended for elderly users. Due to miscellaneous deficits in elderly users' senses, psychologists suggest also multimodality of communication, preferably audio-visual. Some users may prefer voice commands or auditory displays supporting visual stimuli rather than a single modality of interaction. At the same time, voice synthesizers and high tones in sounds are recognized as unpleasant by older adults.(Billis et al., 2010).

Another set of requirements concerns virtual simulation scenarios (experience flow) which should gradually introduce new elements and challenges. Besides some introductory exercises familiarizing users with a virtual environment interface, adequate stimulation pace – adjustable to individual perception requirements, should be provided. In the further stages of experiments, appropriately staged training and an extensive number of hints are more than recommended. Additionally, the ecological validity paradigm recommends the exploitation of well-known real environment elements rather than abstract ones, i.e. phantasy, etc.

The level of task difficulty should be both acceptable for elderly users as well as adequately challenging. Task difficulty should balance easiness and challenge. Too much of the former usually results in boredom and overstimulation which may result in discouragement. The level of difficulty should increase gradually. One innovative method that can help organise the level of difficulty for older adults is based on the impression curve (Anrzejczak, 2020). Environment designers should also avoid multitasking, which can become troublesome especially when operating with new technologies – something that is ubiquitous in virtual environment infrastructure. New technology interface operating skills might arise simultaneously with user experience, but if not, the skills should be supplemented by adequately designed and elaborated tutorials and introductory warm-up tasks.

Cognitive tasks should also address many rules to evoke expected consequences in real-life cognitive activity. Preferably, implemented tasks should consider prospective memory estimation. The malfunctioning of this type of memory influences the perception of the person in real life as unreliable and disorganized. Operational memory and coding new information in long-term memory should especially be intensively trained as this helps real-life skills development.

Ecologically relevant challenges should be designed in such a way that users themselves "figure out" the puzzle solution and best remember the information given – without being given a direct key. The environment interface should also respect individual, though different, cognitive styles.

Motor-Related Limitations

Motor-related tasks, conducted within virtual environments, especially immersive ones, may become extremely challenging for elderly people. Visual stimuli presented with immersive displays (especially head-mounted displays) deprives people of ground (physical environment) reference points. Additionally, unsupervised control over the digital camera or its uncalibrated navigation may result in nausea and physical discomfort, which may result in discouragement towards using the VR system. At the same time, physical activities, performed by moving the limbs and tracked with dedicated controllers, should provide visual feedback and be mapped onto avatar or virtual objects' behaviour. Otherwise, miscorrelation between proprioceptive systems and visual stimuli usually result in nausea and cybersickness. Thus, an appropriate design, as well as elderly-oriented navigation and interaction modes, seem to be more than necessary. Challenges concerning VR interaction in motor rehabilitation include the limited feasibility of VR training, lack of functional relevance and adequate feedback caused by a shortage of environmental factors that link to motor performance (Teo et al., 2016).

A constraints-aware philosophy of user interface design should correlate with observations articulated by physiotherapists. Intuitive and understandable correspondence between body activity and visual stimuli does not seem to be satisfactory for efficient motor rehabilitation. One of the suggestions is that physiotherapy-efficient systems might monitor the intensity of users' physical effort, e.g. by measuring heart rate during a task/exercise, instead of, or simultaneously checking the frequency of the performed movements. Thanks to this, planned, structured and purposeful physical activity can be used. In this way, body performance and fitness can be better stimulated. The second observation postulates the possibility of measuring range of motion by a system that can help monitor limited mobility resulting from limited daily movement. Maintaining the correct ranges of motion or extending it among people suffering from contractures is one of the priorities of geriatric physio prophylaxis. Adequate mobility in the joints determines the appropriate posture that allows functional movement in everyday life. Another observation concerns the dosing of external resistance. Physiotherapists have noticed that reducing daily exercise reduces muscle strength and causes muscle tissue atrophy (sarcopenia). Resistance exercises are the main means of preventing these ailments, additionally they will also contribute to the increase of bone mass, reducing the symptoms of osteopenia which usually develops into osteoporosis. Additionally, among older people, balance training is recommended, which contributes to the reduction of falls in this age group (WHO, 2020).

The literature also claims that dynamic and reactive virtual environments should be avoided. This observation may be due to the common delayed reactions among seniors that may have a demotivating effect when unsupervised. In such a situation, it seems sensible to adapt environmental variability to the user's mental state and predisposition. Some authors have advocated the consideration of reaction time and action dynamics as a factor that may become apparent with the user's experience and practice (Su et al., 2013, Antunes et al., 2017, Rutkowski et al., 2021).

METHODOLOGY

Data for this work was collected based on the exploration of leading publishers' databases: Elsevier, Wiley, PsychArticles, Pubmed, Medline, ACM, WoS. The inclusive criteria for cognitive and motor training in immersive virtual environments concerned both keywords sets and year of publication. The cognitive functions were addressed by key phrases: "cognitive functions", "cognitive interfaces", "cognitive skills", and "cognitive games". The aspects of motor skills were fulfilled by the phrases: "motor functions", "motor skills", "exergaming interfaces", "exertion" and "physical treatment". All of the above issues were considered in the context of virtual reality technologies which was addressed by means of the following phrases: "virtual reality", "virtual environment", "immersive interfaces", "interactive interfaces", "technology", and "interface". Potential beneficiaries of virtual systems are to be elderly people who were retrieved from the context of analyzed research by means of the subsequent phrases: "elderly people", "cognitive ageing", "cognitive impairment", and "physical impairment". The publications were analyzed from the perspective of the last five years. Due to rapidly developing virtual reality technologies, especially in recent times, a limited time period seems to provide a complex and adequately representative review of advanced solutions to cognitive and motor stimulation among the elderly. It must be noted that all inclusive criteria resulted in a very limited number of manuscripts simultaneously addressing all the aforementioned keywords, thus the scoping review was extended by selected research which investigates limited modalities only or discusses cognitive or motor aspects in non-immersive scenarios.

All selected manuscripts were discussed from different perspectives in an interdisciplinary team composed of computer scientists, psychologists and physiotherapists. Such a multiperspectival evaluation, addressing the functionality of the systems in the context of the expectations and capabilities of older adults, adds additional value to the presented review, as there is no universally accepted and recognized methodology for critically evaluating the functionality of immersive virtual reality systems across the aforementioned disciplines.

EVALUATION OF EXISTING COGNITIVE AND MOTOR STIMULATING VIRTUAL ENVIRONMENTS

There are several approaches towards elderly-oriented virtual environment usability metrics in the literature, which might be exploited for the evaluation of existing VR-based motor and cognition training systems. For example, in one recent review, Tuena et al. (2020) presented a systematic evaluation of non-immersive VR systems with particular attention paid to motor/physical rehabilitation. The authors quite extensively systemized usability, user experience and feasibility evaluation of VR systems for monitoring and rehabilitation in healthy and pathological ageing. The recommended technology evaluation methods referred to the Technology Acceptance Model (TAM), the User-Centred Design approach or its modification, namely the Senior Citizens' Acceptance of Information Systems (SCAIS) questionnaires. Concerning the assessment of the usability of VR systems, a wide range of quantitative and qualitative methods were proposed. Among others, System Usability Scale (SUS) questionnaires or User Experience (UX) questionnaires are usually preferred. These well-established methodologies may become pointers for further immersive VR systems evaluation, but they require direct examination of subjects with the specific systems. Due to the very limited direct accessibility of VR systems and a lack of reviews regarding immersive virtual environments evaluation, we propose a critical functional evaluation based on the collation of expectations arising from psychologists’ and physiotherapists’ recommendations, with a documented potential of the immersive VR systems.

Even though Tuena et al. have reported just a few immersive VR environments (Fordell et al., 2011, Corno et al., 2014, Pedroli et al., 2018, Trombetta et al., 2017, Plechata et al., 2019) which accounted for only 8% of the total reviewed VR systems, plenty of research has indirectly imposed requirements on VR systems' functionality. The provided review may become a nucleus of immersive VR systems’ functionality evaluations that may result in a set of design recommendations, usable for the domain community. It is particularly important since off-the-shelf immersive VR hardware has become increasingly affordable and available for the elderly. Although the main target recipients are people with decent computer experience and those who are not afraid to experiment with new technologies, older people are becoming indirect beneficiaries of the emerging systems. At the same time, it should be noted that immersive VR systems are usually not created with the elderly in mind, who usually have a different set of expectations. Elderly-oriented immersive VR systems are still rare. The authors of this review claim that criticisms of immersive VR systems, particularly when compared to non-immersive systems, result from the inadequate exploration of the domain and the selective application of guidance from psychologists and physiotherapists.

For example, Corno et al. (2014) have reported, among others, that multitasking in virtual reality induced cybersickness symptoms, interaction with the controller (wand) was cumbersome and instructions were hard to remember. Placheta et al. (2019) reported that immersive VR systems (i.e. exploiting Head Mounted Displays), in comparison with non-immersive VR systems, deteriorates memory performance. Tuena et al. (2019) have argued that executive functions of older adults (over 65 years old) are overloaded by input devices and consequently weaken memory performance. Some of the authors reported the attractiveness of immersive virtual supermarket shopping tasks, but among young rather than older adults. The authors' conclusions suggested general non-immersive scenarios for older adults.

On the other hand, Fordell et al. (2011) reported that a VR version of the "paper and pencil" tests revealed higher performance than classic evaluation among post-stroke patients. Semi-successful experiments with a fully immersive version of a VR motion rehabilitation system were discussed by Trombetta et al. (2017). The authors suggested that a semi-immersive rehabilitation system was more comfortable for post-stroke patients than a fully immersive one (third-person perspective).

The optimism and prospects for the development of immersive systems have been emphasized by Plechata et al. (2019), who recommend further investigation in immersive technology as rapid technical development causes costs reduction and may benefit from a reduced cybersickness effect in comparison with desktop-based VR. Even though several authors (Corno et al., 2014, Pedroli et al., 2018, Plechata et al., 2019) considered the non-HMD system as better for elderly people, Huygelier et al. (2019), recently postulated that older adults can positively accept and tolerate HMD VR.

The potential of VR is still uncovered as many authors report that non-immersive VR-based rehabilitation is not significantly more beneficial, comparing to conventional rehabilitation, likely due to the lack of relevant tasks provided by immersive VR systems (Saposnik, 2016). The relevancy and functionality issues become the essence of this study.

The core functional objectives to be addressed encompass the elaboration of user interfaces' requirements as well as content and structure of the virtual exercises/experiences. VR controllers and their friendly use without professionals' assistance is necessary to provide training autonomy, i.e. at home. The key role lies in appropriate feedback that fosters or inhibits specific users' behaviours. The structure of the experiments should be well balanced and address complementary senses in progressively more difficult challenges.

Considering the above as well as psychologists' and physiotherapists' recommendations, the subsequent evaluation aspects are proposed for consideration in the conducted review:

1. Ecological validity of environment, provided through an engaging flow of environment, adequate hints and feedback, allowing for self "figure-out" set tasks;
2. Multitasking which integrates complementary cognition and motor stimulation, secure and assuring overloading prevention;
3. Multimodal communication (audio, video, feedback, etc.) taking into account possible auditory and visual changes of the elderly;
4. Cybersickness prevention due to adequate dynamism of the environment and appropriate navigation modes;
5. Addressing a wide scope of cognitive issues, like attention, perception, memory, cognitive styles, and executive functions;
6. Differentiation of motor training taking into account their intensity, dosage of external resistance and the implementation of balance positions, taking into account the physical fitness (including ranges of movement, the possibility of maintaining a standing / sitting position, respiratory capacity) of the recipient.

Proposed criteria become a novel framework for a functional evaluation of immersive VR systems from the perspective of motor training, cognitive rehabilitation and dual-task motor-cognition activity.

Motor Functions Perspective

Motor training is one of the popular applications of VR systems, but it is a real scarcity among immersive systems. Among the few, Arlati et al. (2019) have presented a SocialBike system (successor of Positive Bike system) which performs a home-based dual-task (motor and cognitive) exergame intervention to prevent falls in frail elderly persons. It is a multiplayer, collaborative or competitive, exergaming virtual environment performed in an immersive CAVE or normal screen settings. In the context of motor activity, it stimulates balance improvement and gait patterns. A workload of the cycle ergometer allows the user to maintain a constant level of effort that produces a training effect (65% of the maximum heart rate value). The scenario is performed in the ecological environment of a park (trees, grass, lakes, animals, etc.) where cognitive challenges (objects of certain colour or names starting with certain letters) are provided. The system is supported with several modalities of communication and integration with a social media network. Besides the evident merits of the system, aspects of experiment flow, as well as cognitive improvement, are documented in a very limited manner. The dual-task paradigm, inherently implemented in SocialBike, proves that the problematic nature of multitasking in older adults can be mitigated when designed thoughtfully and argues against the problematic nature of multitasking in older adults. The authors also postulate beneficial results, however, the reports are motor rather than cognition oriented. Among numerous weaknesses of the system, lack of cybersickness prevention should be noted, and limited cognitive stimulation was undisputed.

Huang et al. (2019) examined an immersive VR system for rehabilitation of upper limbs functions in post-stroke patients. The authors planned to assess effectiveness in eliciting upper limb motor recovery in comparison with traditional rehabilitation training, but they have not published the results.

In one recent report, Osaba et al. (2020) investigated the aspects of gait adaptability to discordant sensorimotor stimulations. The study of age-related modifications and propensity for visuomotor adaptations during walking in virtual reality headsets can be easily transferred into immersive virtual rehabilitation scenarios. Older adults, examined during virtual visual perturbations experiments, walked with shorter and slower strides but did not reduce stride velocity nor did they increase stride width variability during mediolateral perturbations. These findings may help in elaborating new methods of digital camera navigation in virtual environments that can help in the identification and remediation of elderly gait deficits.

An elicitation of proxy gestures for locomotion in HMD-based immersive virtual environments in the sitting position was studied by Ganapathi et al. (2019). The sitting position is much more challenging for travelling than natural walking interaction controlled with full-body position tracking. The sitting position does not produce usually vestibular and proprioceptive feedback. Hence it confuses the senses which leads to VR sickness (Bhandari, 2018). The authors have confronted several gestures (calling gesture, bike riding gesture, torso leaning, walk in place, pointing, tapping the legs, etc.) for virtual travel in different virtual environments. They have proved the superiority (appropriateness, effort, ease of use) of selected methods depending on the environmental context. In the process of searching for natural, easy and comfortable methods of virtual travel devoid of the assignment of excessive attention to virtual camera navigation, a hand calling gesture, torso leaning and walk in place achieved the best overall scores regardless of the context.

Complementary distribution of the few immersive motor-related systems is the somewhat more popular non-immersive system. Non-immersive virtual reality solutions have recently become popular, especially in motor rehabilitation. In particular, Microsoft Kinect (Webster & Celik, 2014, Park et al., 2017, Prasertskakul, 2018, Liao et al., 2019, Kamińska et al., 2018) or Nintendo Wii gaming console equipment (Cho, 2014, Molina et al., 2014, Liao et al., 2015) were exploited extensively (Choi et al., 2017). Some of them incorporated a dual-task paradigm for cognitive-motor training (Prasertskakul, 2018, Arlati et al., 2019). There are also numerous attempts to exploit popular tablets or less popular hand gesture controllers (eg. Leap Motion). For example, Crocetta et al. (2018) proposed a Bridge Games non-immersive system consisting of seven logic games requiring some motor interaction performed with selected interaction devices (i.e. tablet, Kinect, Leap Motion, etc.). The goal was to elicit any motor learning.

The examples cited above clearly demonstrate that immersive environments in motor training are rare. This state was confirmed by Amorim et al. (2019), who reviewed the effects of physiotherapeutic interventions with virtual reality treatment (VRT) in balance rehabilitation of the elderly. Even though the authors reported in older manuscripts from 2011 – 2013, they reported a shortage of intervention studies in the elderly using VRT.

Additionally, many teams are trying to impersonate VR systems for the treatment of popular diseases of old age suchs as Parkinson's disease (Pazzaglia et al., 2020), back pain syndroms (Alemanno et al., 2020), obesity (Linge et al., 2021), balance disorders (Li et al., 2021) or osteoarthritis (Byra2020). An important aspect is the possibility of implementing motor and cognitive training among the elderly during an epidemic threat. The use of systems during the COVID-19 pandemic was visible in studies on back pain (Garcia et al., 2021), rehabilitation (Kolbe et al., 2021) or post-stroke physiotherapy (Tran et al., 2021).

On the other hand, a plethora of research, stimulated by the rapid development of VR technologies, provides conclusions on user-friendly navigation and interaction within immersive VR systems mitigating the cybersickness effect (Stanney et al., 2020). Computing performance allows for more sophisticated multimodal communication and high-quality rendering of ecologically oriented environments. Ultimately, contemporary psychological and physiotherapy research findings allow much better design of multi-sensory motor-cognitive exercises that address a range of social needs of older people. All this, complemented by recent achievements and experiences in the area of gamification, provides an almost unlimited workshop allowing for the creation of immersive, attractive and useful virtual simulations for older adults (Tuveri et al., 2016, Martinho et al., 2020). The main obstacle that probably explains the small number of such systems on the market is the high cost of production of such systems and the yet-insufficient number of specialists designing functional and useful interactive immersive virtual environments dedicated to elderly people.

Cognitive Functions Perspective

Stimulating cognitive functions with digital games and interactive virtual environments is not a trivial task. Many authors have investigated the protocols of cognitive neurorehabilitation, training cognitive skills and their near and far transfer to daily routines, but the results are not cohesive. For example, Bediou et al. (2018) have shown how first-person shooter games require repeated practice on selected target cognitive skills within a variety of settings to be successful, whereas Parong et al. (2020) have shown that playing for a short period with immersive virtual environment off-the-shelf brain-training games may not be effective for training cognitive skills. In consequence, recent advancements suggest design rules shift towards more focused games, designed on cognitive principles of skills learning with the extensive role of immersive virtual environments. One of the main goals of the provided review is an elicitation of design principles for cognitive neurorehabilitation and training in immersive virtual environments.

Cognitive principles were analyzed mainly individually and from different perspectives (Fang, 2019), but they were not aggregated and analyzed from the perspective of immersive virtual environments. Selected studies concentrated on interface usability (Jerald et al., 2017) and designed environment immersive-ness (Dinet & Kitajima 2018). Other authors (Vitiello & Sebillo, 2018) have noticed that especially when dealing with categories of disadvantaged users, both impaired as well as healthy users, empowerment goals are paramount to gain the true usability of a given application.

Benoit et al (2015) indicate that realistic virtual environments can be well tolerated by the elderly without noticeable evidence of the cybersickness effect. Graf et al (2020)) have shown that virtual natural environments can provide stimulating experiences, elicit positive emotions and provoke relaxation. Even though Gamito et al. (2020) showed positive outcomes of naturalistic virtual environments' cognitive interventions based on everyday life tasks (executive functions, attention, visual memory, etc.) Parong et al. (2021) reported higher emotional arousal, more extraneous cognitive load and lower engagement negatively affecting learning outcomes within immersive virtual reality learning systems. One of the reasons for inducing cognitive excessive challenge lies in human-computer interface (Banville et al., 2017) and task design. The ecological validity of immersive virtual shopping and the length of movement in VR shopping becomes concordant with multi-layered learning effects (i.e. visuospatial, strategic, verbal) and task performance when designed with an adequate time budget for shopping (Grewe et al., 2013). Even though the performance of VR experiences (i.e. shopping) in immersive VR can become lower among seniors than in non-immersive environments (Plechata et al., 2019), highly immersive technology has good acceptance among ageing adults, which has implications for engagement and further use of HMDs in cognitive assessment and remediation.

At the same time, we should not forget about experiences related to non-immersive environments. Though Faria et al. (2016) marginalized several important issues like usability and functionality of the system, they considered beneficial ecological validity accessible through VR non-immersive technologies on memory, attention, visuospatial abilities and executive functions. Similarly, Reinhardt et al. (2020) proposed an interesting method for measuring mental effort via entropy in VR controller movements. Intelligent user interfaces are capable of detecting mental effort in VR and can detect when users may need assistance in decision making. These valuable findings might be transferred into immersive systems.

Several years ago Larson et al. (2014) published a review of virtual reality cognitive rehabilitation approaches. The authors' conclusions postulated the enrichment of virtual environments with haptic sensory input in addition to visual and auditory inputs and the exploitation of commercially available gaming systems to provide widespread telerehabilitation services. These findings are still valid but more achievable. Due to advancements in technology, multimodal communication can be relatively easily provided and supplemented with various visual, tactile (oscillation) or audio feedback.

It is increasingly common to find multitasking VR scenarios. For example, the benefits of cognitive-motor dual-tasking, in a non-immersive VR environment, had a positive impact on selected cognitive functions and inhibitory control as well as processing speed, attentional and inhibitory control (Wollesen et al., 2020). However, it must be noted that the selection of tasks and the whole experience scenario that stimulate several cognitive abilities seems unsatisfactorily systemized. The selection of tasks that cognitively stimulate older adults is mainly driven by the hardware layer of a system. Intentional multitasking most often occurs in the combination of cognitive and motor training, whereas the scenarios into which diversified cognitive tasks are arranged are most often secondarily inferred from the context of ready-made games or very simple systems. Multitasking issues are mapped on the existing system functionalities rather than basing constituted system functionalities on critical analyses of cognition functionality. Practically absent nowadays are systems whose construction derives, what is documented, directly from the needs of older people, designed by psychologists and made with the attitude towards progressive and complementary training of older people.

Summing up, the widely reported hopes directed towards VR systems, especially immersive ones, have not yet provided enough examples or design principles that can be used to popularize the creation of immersive systems that would benefit from their attractiveness. We believe that the aforementioned range of solutions, taken from non-immersive systems, complemented by experiments on the perception of immersive environments by older adults, can contribute to the development of dedicated, functional VR immersive systems for cognitive training.

Motor-Cognitive Scenarios

Connectivity between motor and cognitive functions is particularly noticeable if natural symptoms of ageing or various diseases, e.g. Parkinson's disease, that humans start to suffer in late adulthood are present (Lang et al., 2020). It is then that the process of declining cognitive and motor functioning is often observed. Even though the most frequent scenario regards individual motor or cognitive treatment there are selected authors postulating cognitive-motor dual-task training. Simultaneous stimulation of both cognitive and motor functions provides more comprehensive stimuli and usually results in more spectacular results rather than in the case of individual, single-modality scenarios.

Among dual-task, cognitive-motor training systems, immersive virtual reality systems are quite scarce. Most of the solutions cover non-immersive scenarios or provide invaluable findings which can be indirectly transferred into immersive virtual scenarios.

For example, Wen et al. (2021) published a narrative review analyzing the development and application of BCI-VR training systems in the rehabilitation of neurological diseases from the perspective of the BCI paradigms (motor imagery, event-related potential like e.g. P300, steady-state visually evoked potential) and provided a pathway for further research in this field. Among others, they have analyzed the BCI-VR simulation control loop in which BCI interfaces exploit the motor imagery paradigm in the recovery of motor functions, attention controled VR games for ADHD treatment or navigation ability improvement among pateints with spinal cord injuries. The authors concentrated on neurological diseases rehabilitation, where BCI paradigms are the only means of application control, thus the potential of cognitive and motor functions of healthy seniors remained beyond the scope of Wen's review.

One of the few examples exploiting the dual-task paradigm for both cognitive and motor functions training among older adults was described by Pedroli et al. (2018). A Positive bike system consists of a cycle-ergometer integrated into an immersive reality CAVE system, which combines motor and cognitive exercises, assuring enjoyable user experiences. The merits of the system were described above in the review.

Cognitive-motor training for adults at high Alzheimer's disease risk was presented by Doniger et al. (2018). In one of the scenarios, the authors exploited a non-immersive virtual environment (monitor + treadmill) with "real-world" tasks targeting sustained and selective attention, working memory, covert rule deduction, and planning. The authors suggest that cognitive training improves cognitive function and a more ecologically valid cognitive-motor VR setting that better mimics complex daily activities may augment the transfer of trained skills. Besides well documented selected cognitive issues, the aspects of immersive-ness, multimodal communication, presence, comfort, functionality and motor-related issues were not addressed by the authors.

Dual-tasks were researched by Tacchino et al. (2020). They investigated cognitive-motor interference among people with multiple sclerosis. According to the authors, traditional interventions may not adequately prepare patients to face the challenges of most daily living activities. However, the authors exploited a non-immersive tablet-based application. Though usable, motivating and well accepted by people, the application was not autonomous as it required therapists' control. It is worth noticing that examined subjects expressed that they intended to choose scenarios and levels of difficulty by themselves, which was not available in the experiment.

Kannan et al. (2019), in turn, evaluated the efficacy of non-immersive cognitive-motor exergame training for improving balance control and cognition among people with chronic strokes. Patients exploited the Wii Fit gaming platform in conjunction with performing cognitive tasks. This off-the-shelf solution, though usable in provided context, was not examined among healthy adults who want to take care of their physical and mental condition. The differences between immersive and non-immersive environments make this research just contextual support for ecologically valid, multitasking, immersive solutions.

Mrakic et al. (2018), on the other hand, evaluated the impact of a VR-based program combining aerobic exercise and cognitive training for subjects with mild cognitive impairment. The results were more promising than conclusive. The VR non-immersive environment exploited a cycle-ergometer and screen display situated in front of a subject. All the scenarios (trail in a park, urban scenario, supermarket), except one, did not report a level of difficulty. The level of difficulty was accomplished by incorporating distractors (similar to the intended target, semantic similarity to the target, formats and discounted products of the same products) in order to increase attentional and visuospatial demands. This study is only partially related to the focus area of this paper and contributes to motoric training.

SUMMARY

A systematic, functionality scoping analysis of state-of-the-art VR-based motor-cognitive rehabilitation systems evidently reveals a shortage of immersive multitask environments. This is puzzling since many researchers have investigated individual cognitive or motor stimulating modalities and proclaimed their interdependence and mutual support. Designers of cognitive-motor training environments concentrate more on patients with selected diseases rather than normally ageing adults. Ecological validity is rather occasional as most dual-task environments are based on off-the-shelf sports games or eye-friendly sightseeing rather than dedicated, engaging and cognitively demanding virtual environments. Individual exceptions are recurring and include supermarket shopping or trail rides. As the immersion increases, the monotonicity of the experience also increases. At the same time, the "flow" of the scenario and the range of cognitive exercises decrease. For example, there is a lack of immersive experiences with covert rule deduction, in which participants (older adults) "figure out" the rules of the challenge on their own.

The multitasking paradigm is usually limited to dual-task exercises. More sophisticated motor activities, monitoring the intensity of effort, range of movements, dosing external resistance are quite scarce and limited to professional diagnostic medical systems. Social Bike is among the few exceptions. Analogically cognitive challenges are very limited when co-existing with motor challenges or are servile to the hardware interface or off-the-shelf gaming scenarios, which are usually imposed by different target users and do not correspond to elderly-dedicated requirements.

There is a paucity of published research aiming to recognize the evident potential of multimodal communication with virtual environment systems. This is due to the rapid development of virtual environment interfaces (i.e. HMDs by HTC, Oculus), whose performance, supported by artificial intelligence provide capabilities at yet unconsumed by immersive environments dedicated to the elderly. The experiments are dominated by the default hardware infrastructure configurations that are provided by global vendors. Few examples involve non-immersive environments, but solutions that combine motor and cognitive challenges are non-existent in popular immersive variants using popular off-the-shelf VR HMDs.

An additional challenge is to develop interaction mechanisms in immersive environments that minimize vulnerability to simulator sickness among older adults. Although cybersickness comfort was monitored in some experiments, configuring complex cognitive-motor immersive experiments that provide pleasant sensations among older adults becomes an intricate endeavour and requires further in-depth research.

REFERENCES

Alemanno, F., Houdayer, E., Emedoli, D., Locatelli, M., Mortini, P., Mandelli, C., ... & Iannaccone, S. (2019). Efficacy of virtual reality to reduce chronic low back pain: Proof-of-concept of a non-pharmacological approach on pain, quality of life, neuropsychological and functional outcome. *PloS one*, *14*(5), e0216858.

Amorim, J. S. C. D., Leite, R. C., Brizola, R., & Yonamine, C. Y. (2019). Virtual reality therapy for rehabilitation of balance in the elderly: a systematic review and META-analysis. *Advances in rheumatology*, *58*.

Andrzejczak, J., Osowicz, M., & Szrajber, R. (2020, June). Impression curve as a new tool in the study of visual diversity of computer game levels for individual phases of the design process. In *International Conference on Computational Science* (pp. 524-537). Springer, Cham.

Antunes, T. P. C., de Oliveira, A. S. B., Crocetta, T. B., de Lima Antão, J. Y. F., de Almeida Barbosa, R. T., Guarnieri, R., ... & de Abreu, L. C. (2017). Computer classes and games in virtual reality environment to reduce loneliness among students of an elderly reference center: study protocol for a randomised cross-over design. *Medicine*, *96*(10).

Arlati, S.; Colombo, V.; Spoladore, D.; Greci, L.; Pedroli, E.; Serino, S.; Cipresso, P.; Goulene, K.; Stramba-Badiale, M.; Riva, G.; Gaggioli, A.; Ferrigno, Ge.; Sacco, M. A Social Virtual Reality-Based Application for the Physical and Cognitive Training of the Elderly at Home. *Sensors* **2019**, *19*, 261. https://doi.org/10.3390/s19020261

Bohil, C. J., Alicea, B., and Biocca, F. A. (2011). Virtual reality in neuroscience research and therapy. *Nat. Rev. Neurosci.* 12, 752–762. doi: 10.1038/nrn3122

Banville, F., Couture, J. F., Verhulst, E., Besnard, J., Richard, P., & Allain, P. (2017, July). Using virtual reality to assess the elderly: The impact of human-computer interfaces on cognition. In *International conference on human interface and the management of information* (pp. 113-123). Springer, Cham.

Bauer, A. C. M., & Andringa, G. (2020). The potential of immersive virtual reality for cognitive training in elderly. *Gerontology*, *66*(6), 614-623.

Bediou, B., Adams, D. M., Mayer, R. E., Tipton, E., Green, C. S., & Bavelier, D. (2018). Meta-analysis of action video game impact on perceptual, attentional, and cognitive skills. Psychological Bulletin, 144(1), 77–110. https://doi.org/10.1037/bul0000130

Benoit, M., Guerchouche, R., Petit, P. D., Chapoulie, E., Manera, V., Chaurasia, G., ... & Robert, P. (2015). Is it possible to use highly realistic virtual reality in the elderly? A feasibility study with image-based rendering. *Neuropsychiatric disease and treatment*, *11*, 557.

Bhandari, J., MacNeilage, P., and Folmer, E. (2018). Teleportation without spatial disorientation using optical flow cues. In Proceedings of Graphics Interface (Vol. 2018).

Billis, A. S., Konstantinidis, E. I., Mouzakidis, C., Tsolaki, M. N., Pappas, C., & Bamidis, P. D. (2010). A game-like interface for training seniors' dynamic balance and coordination. In *XII Mediterranean Conference on Medical and Biological Engineering and Computing 2010* (pp. 691-694). Springer, Berlin, Heidelberg.

Byra J, Czernicki K. The Effectiveness of Virtual Reality Rehabilitation in Patients with Knee and Hip Osteoarthritis. J Clin Med. 2020 Aug 14;9(8):2639. doi: 10.3390/jcm9082639. PMID: 32823832; PMCID: PMC7465023

Cho, G. H., Hwangbo, G., & Shin, H. S. (2014). The effects of virtual reality-based balance training on balance of the elderly. *Journal of physical therapy science*, *26*(4), 615-617.

Choi, S. D., Guo, L., Kang, D., & Xiong, S. (2017). Exergame technology and interactive interventions for elderly fall prevention: a systematic literature review. *Applied ergonomics*, *65*, 570-581.

Corno, G., Bouchard, S., and Forget, H. (2014). Usability assessment of the virtual multitasking test (v-mt) for elderly people. *Annual Rev. Cyberther. Telemed.* 199, 168–172.

Crocetta, T., Luciano Vieira de Araújo, Guarnieri, R., Massetti, T., Fernando Henrique Inocêncio, B. F., de Abreu, L. C., & Carlos Bandeira de, M. M. (2018). Virtual reality software package for implementing motor learning and rehabilitation experiments. *Virtual Reality, 22*(3), 199-209. doi:http://dx.doi.org/10.1007/s10055-017-0323-2

Dinet, J., & Kitajima, M. (2018, April). Immersive interfaces for engagement and learning: Cognitive implications. In *Proceedings of the Virtual Reality International Conference-Laval Virtual* (pp. 1-8).

Doniger, G. M., Beeri, M. S., Bahar-Fuchs, A., Gottlieb, A., Tkachov, A., Kenan, H., ... & Plotnik, M. (2018). Virtual reality-based cognitive-motor training for middle-aged adults at high Alzheimer's disease risk: A randomized controlled trial. *Alzheimer's & Dementia: Translational Research & Clinical Interventions*, *4*, 118-129.

Duray, M., & Genç, A. (2017). The relationship between physical fitness and falling risk and fear of falling in community-dwelling elderly people with different physical activity levels. *Turkish journal of medical sciences*, *47*(2), 455-462.

Faria, A. L., Andrade, A., Soares, L., & i Badia, S. B. (2016). Benefits of virtual reality based cognitive rehabilitation through simulated activities of daily living: a randomized controlled trial with stroke patients. *Journal of neuroengineering and rehabilitation*, *13*(1), 1-12.

Fang, Y., Chen, C. H., & Hoe, Z. Y. (2019, March). Spaced retrieval memory training system for elderly: an investigation of design criteria. In *Proceedings of the 2019 7th International Conference on Information and Education Technology* (pp. 269-274).

Fordell, H., Bodin, K., Bucht, G., and Malm, J. (2011). A virtual reality test battery for assessment and screening of spatial neglect. *Acta Neurol. Scand.* 123, 167–174. doi: 10.1111/j.1600-0404.2010.01390.x

Ganapathi, P., & Sorathia, K. (2019). Elicitation Study of Body Gestures for Locomotion in HMD-VR Interfaces in a Sitting-Position. In *Motion, Interaction and Games* (pp. 1-10).

Gamito, P., Oliveira, J., Alves, C., Santos, N., Coelho, C., & Brito, R. (2020). Virtual reality-based cognitive stimulation to improve cognitive functioning in community elderly: A controlled study. *Cyberpsychology, Behavior, and Social Networking*, *23*(3), 150-156.

Garcia LM, Birckhead BJ, Krishnamurthy P, Sackman J, Mackey IG, Louis RG, Salmasi V, Maddox T, Darnall BD. An 8-Week Self-Administered At-Home Behavioral Skills-Based Virtual Reality Program for Chronic Low Back Pain: Double-Blind, Randomized, Placebo-Controlled Trial Conducted During COVID-19. J Med Internet Res. 2021 Feb 22;23(2):e26292. doi: 10.2196/26292. PMID: 33484240; PMCID: PMC7939946.

Graf, L., Liszio, S., & Masuch, M. (2020, September). Playing in virtual nature: improving mood of elderly people using VR technology. In *Proceedings of the Conference on Mensch und Computer* (pp. 155-164).

Grewe, P., Kohsik, A., Flentge, D., Dyck, E., Botsch, M., Winter, Y., ... & Piefke, M. (2013). Learning real-life cognitive abilities in a novel 360-virtual reality supermarket: a neuropsychological study of healthy participants and patients with epilepsy. *Journal of neuroengineering and rehabilitation*, *10*(1), 1-15.

Huang X, et al. (2017). Clinical effectiveness of combined virtual reality and robot assisted fine hand motion rehabilitation in subacute stroke patients. *IEEE Int Conf Rehabil Robot*, 511–5.

Huang, Q., Wu, W., Chen, X., Wu, B., Wu, L., Huang, X., ... & Huang, L. (2019). Evaluating the effect and mechanism of upper limb motor function recovery induced by immersive virtual-reality-based rehabilitation for subacute stroke subjects: study protocol for a randomized controlled trial. *Trials*, *20*(1), 1-9.

Huygelier, H., Schraepen, B., van Ee, R., Abeele, V. V., and Gillebert, C. R. (2019). Acceptance of immersive head-mounted virtual reality un older adults. *Sci. Rep.* 9:4519. doi: 10.1038/s41598-019-41200-6

(Jerald2017) Jason Jerald, Joseph J. LaViola, & Richard Marks (2017). VR interactions. In *ACM SIGGRAPH 2017 Courses (SIGGRAPH '17).* Association for Computing Machinery, New York, USA, Article 19, 1-105. https://doi.org/10.1145/3084873.3084900

Jouhki, J. (2019). Humans and their technologies play the infinite game. *Human Technology*, *15*(1), 1–5. https://doi.org/10.17011/ht/urn.201902201605

Kamińska, M. S., Miller, A., Rotter, I., Szylińska, A., & Grochans, E. (2018). The effectiveness of virtual reality training in reducing the risk of falls among elderly people. *Clinical interventions in aging*, *13*, 2329.

(Kannan 2019) Kannan, L., Vora, J., Bhatt, T., & Hughes, S. L. (2019). Cognitive-motor exergaming for reducing fall risk in people with chronic stroke: a randomized controlled trial. *NeuroRehabilitation*, *44*(4), 493-510.\

Kolbe L, Jaywant A, Gupta A, Vanderlind WM, & Jabbour G. (2021). Use of virtual reality in the inpatient rehabilitation of COVID-19 patients. Gen Hosp Psychiatry. 2021 Jul-Aug;71:76-81. https://doi.org/10.1016/j.genhosppsych.2021.04.008. Epub 2021 Apr 29. PMID: 33964789; PMCID: PMC8081572.

Lang, S., Ismail, Z., Kibreab, M., Kathol, I., Sarna, J., & Monchi, O. (2020). Common and unique connectivity at the interface of motor, neuropsychiatric, and cognitive symptoms in Parkinson's disease: A commonality analysis. *Human brain mapping*, *41*(13), 3749-3764.

Larson, E. B., Feigon, M., Gagliardo, P., & Dvorkin, A. Y. (2014). Virtual reality and cognitive rehabilitation: a review of current outcome research. *NeuroRehabilitation*, *34*(4), 759-772.

Li F, Harmer P, Voit J, Chou LS. (2021). Implementing an Online Virtual Falls Prevention Intervention During a Public Health Pandemic for Older Adults with Mild Cognitive Impairment: A Feasibility Trial. Clin Interv Aging. 2021 May 25;16:973-983. doi: 10.2147/CIA.S306431. PMID: 34079243; PMCID: PMC8164667.

Liao, Y. Y., Yang, Y. R., Wu, Y. R., & Wang, R. Y. (2015). Virtual reality-based Wii fit training in improving muscle strength, sensory integration ability, and walking abilities in patients with Parkinson's disease: a randomized control trial. *International Journal of Gerontology*, *9*(4), 190-195.

Liao, Y. Y., Chen, I. H., & Wang, R. Y. (2019). Effects of Kinect-based exergaming on frailty status and physical performance in prefrail and frail elderly: A randomized controlled trial. *Scientific reports*, *9*(1), 1-9.

Linge AD, Jensen C, Laake P, Bjørkly SK. (2021). Lifestyle and Work-Related Factors Associated with Work Ability and Work Participation for People with Obesity: A Prospective Observational Study After Vocational Rehabilitation. Diabetes Metab Syndr Obes. 2021 Jun 29;14:2943-2954. https://doi.org/10.2147/DMSO.S311462. PMID: 34234492; PMCID: PMC8254537.

Martinho, D., Carneiro, J., Corchado, J. M., & Marreiros, G. (2020). A systematic review of gamification techniques applied to elderly care. *Artificial Intelligence Review*, *53*(7), 4863-4901.

Molina, K. I., Ricci, N. A., de Moraes, S. A., & Perracini, M. R. (2014). Virtual reality using games for improving physical functioning in older adults: a systematic review. *Journal of neuroengineering and rehabilitation*, *11*(1), 1-20.

Mrakic-Sposta, S., Di Santo, S. G., Franchini, F., Arlati, S., Zangiacomi, A., Greci, L., ... & Vezzoli, A. (2018). Effects of combined physical and cognitive virtual reality-based training on cognitive impairment and oxidative stress in MCI patients: a pilot study. *Frontiers in aging neuroscience*, *10*, 282.

Murman, D. L. (2015, August). The impact of age on cognition. In *Seminars in hearing* (Vol. 36, No. 03, pp. 111-121). Thieme Medical Publishers.

Osaba, M. Y., Martelli, D., Prado, A., Agrawal, S. K., & Lalwani, A. K. (2020). Age-related differences in gait adaptations during overground walking with and without visual perturbations using a virtual reality headset. *Scientific Reports*, *10*(1), 1-10.

Park, D. S., Lee, D. G., Lee, K., & Lee, G. (2017). Effects of virtual reality training using Xbox Kinect on motor function in stroke survivors: a preliminary study. *Journal of Stroke and Cerebrovascular Diseases*, *26*(10), 2313-2319.

Parong, J., & Mayer, R. E. (2020). Cognitive consequences of playing brain-training games in immersive virtual reality. *Applied Cognitive Psychology*, *34*(1), 29-38.

Parong, J., & Mayer, R. E. (2021). Cognitive and affective processes for learning science in immersive virtual reality. *Journal of Computer Assisted Learning*, *37*(1), 226-241.

Pazzaglia C, Imbimbo I, Tranchita E, Minganti C, Ricciardi D, Lo Monaco R, Parisi A, Padua L. (2020). Comparison of virtual reality rehabilitation and conventional rehabilitation in Parkinson's disease: a randomized controlled trial. Physiotherapy. 2020 Mar;106:36-42. doi: 10.1016/j.physio.2019.12.007. Epub 2019 Dec 23. PMID: 32026844.

Pedroli, E., Greci, L., Serino, S., Cipresso, P., Arlati, S., Mondellini, M., et al. (2018). Characteristics, usability, and users experience of a system combining cognitive and physical therapy in a virtual environment :positive bike. *Sensors* 18:2343. doi: 10.3390/s18072343

Plechatá, A., Sahula, V., Fayette, D., and Fajnerová, I. (2019). Age-related differences with immersive and non-immersive virtual reality in memory assessment. *Front. Psychol.* 10:1330. https://doi.org/10.3389/fpsyg.2019.01330

Prasertsakul, T., Kaimuk, P., Chinjenpradit, W., Limroongreungrat, W., & Charoensuk, W. (2018). The effect of virtual reality-based balance training on motor learning and postural control in healthy adults: a randomized preliminary study. *Biomedical engineering online*, *17*(1), 1-17.

Reinhardt, D., Hurtienne, J., & Wienrich, C. (2020, March). Measuring Mental Effort via Entropy in VR. In *Proceedings of the 25th International Conference on Intelligent User Interfaces Companion* (pp. 43-44).

Riches S, Azevedo L, Bird L, Pisani S, Valmaggia L. (2021). Virtual reality relaxation for the general population: a systematic review. Soc Psychiatry Psychiatr Epidemiol. 2021 Oct;56(10):1707-1727. doi: 10.1007/s00127-021-02110-z. Epub 2021 Jun 13. PMID: 34120220; PMCID: PMC8197783.

Riva, G., and Waterworth, J. A. (2014). Being present in a virtual world. In *The Oxford Handbook of Virtuality*, ed M. Grimshaw (Oxford: Oxford University Press), 205–221. https://doi.org/10.1093/oxfordhb/9780199826162.013.015

Rutkowski, S., Adamczyk, M., Pastuła, A., Gos, E., Luque-Moreno, C., & Rutkowska, A. (2021). Training Using a Commercial Immersive Virtual Reality System on Hand–Eye Coordination and Reaction Time in Young Musicians: A Pilot Study. *International Journal of Environmental Research and Public Health*, *18*(3), 1297.

Saposnik G, et al. (2016). Efficacy and safety of non-immersive virtual reality exercising in stroke rehabilitation (EVREST): a randomized, multicentre, single-blind, controlled trial. *Lancet Neurol, 15*(10) 1019–27.

Stanney, K., Lawson, B. D., Rokers, B., Dennison, M., Fidopiastis, C., Stoffregen, T., ... & Fulvio, J. M. (2020). Identifying causes of and solutions for Cybersickness in immersive technology: reformulation of a research and development agenda. *International Journal of Human–Computer Interaction, 36*(19), 1783-1803.

Su, K. W., Chen, C. J., & Shue, L. Y. (2013). Implication of Cognitive Style in Designing Computer-Based Procedure Interface. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *23*(3), 230-242.

Tacchino, A., Veldkamp, R., Coninx, K., Brulmans, J., Palmaers, S., Hämäläinen, P., ... & Baert, I. (2020). Design, development, and testing of an app for dual-task assessment and training regarding cognitive-motor interference (CMI-APP) in people with multiple sclerosis: Multicenter Pilot Study. *JMIR mHealth and uHealth*, *8*(4), e15344.

Taipale, S., & Hänninen, R. (2018). More years, more technologies: Aging in the digital era. *Human Technology*, *14*(3), 258–263. https://doi.org/10.17011/ht/urn.201811224833

Teo, W.-P., Muthalib, M., Yamin, S., Hendy, A. M., Bramstedt, K., Kotsopoulos, E., et al. (2016). Does a combination of virtual reality, neuromodulation and neuroimaging provide a comprehensive platform for neurorehabilitation? – a narrative review of the literature. *Front. Hum. Neurosci.* 10:284. https://doi.org/10.3389/fnhum.2016.00284

Tran JE, Fowler CA, Delikat J, Kaplan H, Merzier MM, Schlesinger MR, Litzenberger S, Marszalek JM, Scott S, Winkler SL. (2021). Immersive Virtual Reality to Improve Outcomes in Veterans With Stroke: Protocol for a Single-Arm Pilot Study. JMIR Res Protoc. 2021 May 10;10(5):e26133. https://doi.org/10.2196/26133. PMID: 33970110; PMCID: PMC8145080.

Triberti, S., & Riva, G. (2016). Being present in action: a theoretical model about the "interlocking" between intentions and environmental affordances. *Front. Psychol.* 6, 2052. https://doi.org/10.3389/fpsyg.2015.02052

Trombetta, M., Paula, P., Henrique, B., Brum, M. R., Colussi, E. L., Carolina, A., et al. (2017). Motion Rehab AVE 3D: a VR-based exergame for post-stroke rehabilitation. *Comput. Methods Programs Biomed,* 151, 15–21. https://doi.org/10.1016/j.cmpb.2017.08.008

Tuena, C., Serino, S., Dutriaux, L., Riva, G., & Piolino, P. (2019). Virtual enactment effect on memory in young and aged populations :a systematic review. *J. Clin. Med.,* 8, 620. https://doi.org/10.3390/jcm8050620

Tuena C, Pedroli E, Trimarchi PD, Gallucci A, Chiappini M, Goulene K, Gaggioli A, Riva G, Lattanzio F, Giunco F and Stramba-Badiale M (2020) Usability Issues of Clinical and Research Applications of Virtual Reality in Older People: A Systematic Review. *Front. Hum. Neurosci, 14*, 93. https://doi.org/10.3389/fnhum.2020.00093

Tuveri, E., Macis, L., Sorrentino, F., Spano, L. D., & Scateni, R. (2016, June). Fitmersive games: Fitness gamification through immersive VR. In *Proceedings of the International Working Conference on Advanced Visual Interfaces* (pp. 212-215).

Vitiello, G., & Sebillo, M. (2018, May). The importance of empowerment goals in elderly-centered interaction design. In *Proceedings of the 2018 International Conference on Advanced Visual Interfaces* (pp. 1-5).

World Health Organization. (2015). *World report on ageing and health*. World Health Organization.

WHO Guidelines on Physical Activity and Sedentary Behaviour. Geneva: World Health Organization; 2020. PMID: 33369898.

Webster, D., & Celik, O. (2014). Systematic review of Kinect applications in elderly care and stroke rehabilitation. *Journal of neuroengineering and rehabilitation*, *11*(1), 1-24.

Wen, D., Fan, Y., Hsu, S. H., Xu, J., Zhou, Y., Tao, J., ... & Li, F. (2021). Combining brain–computer interface and virtual reality for rehabilitation in neurological diseases: A narrative review. *Annals of physical and rehabilitation medicine*, *64*(1), 101404.

Wildenbos, G. A., Peute, L., and Jaspers, M. (2018). Aging barriers influencing mobile health usability for older adults: a literature based framework (MOLD-US). *Int. J. Med. Inform.* 114, 66–75. https://doi.org/10.1016/j.ijmedinf.2018.03.012

Wollesen, B., Wildbredt, A., van Schooten, K. S., Lim, M. L., & Delbaere, K. (2020). The effects of cognitive-motor training interventions on executive functions in older people: a systematic review and meta-analysis. *European Review of Aging and Physical Activity*, *17*(1), 1-22.

Authors' Note

This research was carried out as a part of project no. POIR.01.01.01-00-0951/19, entitled: "Grydsen – innovative psychological therapeutic methods for aged people with the use of VR technology", co-financed by the National Center for Research and Development. This article was completed while the second author was a Doctoral Candidate in the Interdisciplinary Doctoral School at the Lodz University of Technology, Poland.

All correspondence should be addressed to
Adam Wojciechowski
Institute of Information Technology,
Lodz University of Technology, Poland,
e-mail: adam.wojciechowski@p.lodz.pl
ORCID 0000-0003-3786-7225

Human Technology
ISSN 1795-6889
https://ht.csr-pub.eu

HUMAN TECHNOLOGY

ISSN: 1795-6889

https://ht.csr-pub.eu

Volume 17(2), October 2021, 164-189

APPLYING ETHOLOGY TO DESIGN HUMAN-ORIENTED TECHNOLOGY. AN EXPERIMENTAL STUDY ON THE SIGNALLING ROLE OF THE LABELLING EFFECT IN TECHNOLOGY'S EMPOWERMENT

Artur Modliński
Faculty of Management
University of Łódź
Poland

Matthew E. Gladden
Center for Artificial Intelligence and Cybercommunication Research
Poland
Georgetown University
USA

Abstract: *We transpose ethological and sociological theory on autonomous technology management using two signals: country of origin and security certificate status. Our research shows that to understand the degree of attractiveness of human-oriented technology that has been techno-empowered, we should analyze the natural interspecies interaction taking place in the ecological niche. A 2×4 between-subject experiment on a fictitious brand was designed to test three hypotheses regarding autonomous office assistant empowerment. Two hundred ninety-five people (54% females) participated in the study. We found that people have a higher intention to use autonomous office assistants if their country of origin is unknown but a security certificate is provided. Gender moderates the 'label effect' so that females have a higher intention to allow autonomous office assistant to make independent decisions if they do not know the country of origin but a safety certificate is provided, whereas for males, neither of these labels influences such intention significantly.*

Keywords: *techno-empowerment, autonomous system, technology acceptance, ethology, country of origin, certification, new technology management.*

DOI: https://doi.org/10.14254/1795-6889.2021.17-2.5

INTRODUCTION

Breakthroughs in research on artificial intelligence and its applicability are changing human organizations. Most significantly, non-human agents are appearing that help organizations fulfil their mission. Here it suffices to mention algorithms that collect and process data (Akerkar, 2019) which organizations use to achieve a competitive advantage (McAfee & Brynjolfsson, 2017); digital workforces that perform tasks faster (Kaplan & Haenlein, 2018) while making fewer mistakes than human beings (Makridakis, 2017); and intelligent systems that optimize the internal environment (Cook et al., 2009) and connect various devices in the workplace (Nappi and de Campos Ribeiro, 2020). Intelligent machines may be "complementary" (CIMs) and/or "substitutive" (SIMs) towards the human workforce (Modliński and Pinto, 2020). SIMs replace people fully in the workplace, which generates criticism for potentially causing structural unemployment (Gilbert & Oladi, 2021) and social polarization (Jones, 2013). CIMs, on the other hand, are based on the assumption that humans and machines may achieve more working together than working independently. The desire to achieve such a human-machine synergy effect has driven the development of organic teams (Daugherty & Wilson, 2018); it is readily visible in healthcare (David, 2017), mechanical industries (Maurta et al., 2017), and security (Winn, 2020, Lyons et al., 2020). Although just a few years ago it was the human being who enjoyed a privileged role in such relationships, that status quo is now being altered.

Throughout the first decade of the Twenty-first century, all non-human agents based on artificial intelligence were subordinate to humans. Thanks to the dynamic development of machine learning, however, such agents are now able to make decisions on their own (Endsley, 2016). The process of transferring autonomy in decision-making to technology has been conceptualized as techno-empowerment (Modliński & Skowroński, 2021). Not surprisingly, the consequences of techno-empowering artificial agents to make significant decisions can be ambiguous. People are, for example, opposed to machines making decisions when human lives or an enterprise's condition depends on them (Modliński, 2021a). Nevertheless, current research shows that machines can make decisions as accurately as human beings – or even outperform them, with regard to their rate of failures (Phillips-Wren and Jain, 2006). This is why the concepts of autonomous vehicles (Beecrof, 2019), autonomous assistants (Daugherty and Wilson, 2018), artificially intelligent cybersecurity (Galina & Zarina, 2019), and smart finance (Pettigrew et al., 2018) are dynamically growing. However, a significant restraining force for autonomous machines is the human feeling of insecurity and fear of such technology.

A key challenge for the effective use of intelligent technologies is the low level of trust possessed by their potential users. There exists a plethora of research regarding human trust and acceptance of such technology (see more: Schaefer et al., 2016), and we will attempt to provide a new perspective on this issue, without exhaustively recounting the existing literature in this text. With regard to the more specific question of trust towards fully autonomous technologies, meanwhile, the literature is more scarce. There are two main bodies of research in the field. The first has been developed by researchers following Bohlen and Beal's (1957) model, which assumes that to increase trust, attitudes, and acceptance, the alpha users (innovators) should primarily be identified and targeted. In consequence, there are several user-oriented studies that have found that people differ in their perceptions of autonomous technology depending on culture (Xu & Fan, 2019), gender (Charness et al., 2019), age, educational background (Hudson et al., 2019), and religion (Modliński et al., 2021). Some of the research, however, has provided contradictory results (Tennant et al., 2019). The second stream of research is more machine-oriented, as its authors try to identify what features of machines increase human attitudes and trust towards such technology. Two substreams may be named here: research focused on appearance (RFA), and research focused on behavior (RFB). RFA investigates the role of embodiment in machines' acceptance. Researchers working in this field are highly focused on anthropomorphic cues (Waytz et al., 2014, De Visser et al., 2017), suggesting that the more humanlike an embodiment a machine possesses, the higher the acceptance and trust by its users (Boray et al., 2021). RFB, on the other hand, investigates the influence of a machine's behavior on its acceptance, suggesting, e.g., that a machine's display of empathy (Pelatu et al., 2021) or use of humor (Tay et al., 2016) or persuasion (Fogg, 2003) increases its chances of gaining human acceptance. Although there has been research connected with the natural sciences explaining, e.g., the role of oxytocin on trust towards machines (De Visser et al., 2017), such interdisciplinary approach is extremely rare in the current literature. Inspired by the research lacunas identified by Hancock et al. (2011), we believe that the problem of autonomous machines' acceptance may be considered from yet another perspective: that of natural interactions between actors in an ecological niche. Our paper offers three contribution to current theory and practice. First of all, we show that a country-of-origin label may deter customers from empowering or using empowered technology. Second, we found that a safety certificate serves as an encouraging signal that increases human beings' intention to empower autonomous assistants. Third, we demonstrate that the labelling effect is stronger in females than males, which suggest that companies primarily targeting females should pay greater attention to what signals they are really sending.

For these reasons, we – first of all – refer to ethology and signalling theory to provide a general picture of the so-called "labelling effect" and then transpose it to autonomous technology management. We presume that labels may be compared to the signals that living organisms detect in nature and use to estimate risk. Two such labels are frequently provided in the case of advanced technology: country of origin and safety certificates. Second, we describe the country-of-origin (COO) label in the context of autonomous technology's empowerment. We found that although the COO effect is one of the most described concepts in marketing literature, there is not yet any research suggesting how it relates to technology making autonomous decisions. Third, we describe the certification effect in the high-tech industry, suggesting that it may serve as an encouraging signal for potential users. We then refer to differences between males and females in the receiving of signals and contextualize them with the aid of cultural and ethological theories. Finally, we construct the model which we test in the experimental study.

CONCEPTUAL BACKGROUND

Labels and signalling theory

Each organism on Earth lives in some ecological niche and has specific functions within it. While for Grinnell (1917) a niche is a specific physical place of an organism in an ecosystem, for Elton (2001) a niche indicates an organism's particular place in the structure and in interspecies interactions. These interactions can be antagonistic or non-antagonistic (Krebs, 2008). Non-antagonistic interactions mean that neither side of the interaction is harmed but sometimes may benefit. Such interactions include symbiosis (mutual benefit) and commensalism (one-sided benefit) (Krebs, 2008). Antagonistic interactions, on the other hand, mean that the relationship will prove unfavorable for at least one side. Examples of such interactions are competition (the fight for a common resource), parasitism (where the coexistence of organisms benefits only one of them), and predation (where one side of the interaction is killed and consumed). As it is presumed that the primary function of any organism is survival and development, it enters into various relationships with representatives of its own and other species in order to achieve that goal. Examples include mating in order to pass on genes to the next generation (reproduction), forming a herd (protection), creating tools (more efficient access to resources), or struggling for territory (maintaining a place in a niche).

Practical example 1 – Rethink Robotics and the idea of cobotics
One of the more popular emerging ideas related to industrial technology that is based on a commensalistic relationship between machines and humans is that of 'cobotics.' Cobotics is a combination of the words 'collaborative' and 'robots'; it presumes that e-synergy can be achieved by designing friendly cooperation between agents. One of the pioneers in this area has been the organization Rethink Robotics, which designs solutions that are based on close cooperation between humans and machines and that make use of their unique skills. Moreover, in their model, a robot is designed to send positive signals to employees. As part of this concept, we can meet machines with screens that use facial expressions and voice modulation, that initiate conversations, and that learn the preferences of employees.

To survive and develop in a niche, organisms must somehow be able to recognize the forms of interaction they enter into. According to this logic, they generally attempt to engage in non-antagonistic interactions and avoid antagonistic interactions that are unfavorable to them. They are able to do this thanks to signals that have developed through the process of evolution. Living organisms send signals that allow another party to enter into interaction or avoid it; each animal species uses specific signals that, thanks to natural selection, are continually changing. It is crucial for a living organism to recognize such signals, as this allows it to take advantage of opportunities or avoid dangers. Some animals have even developed mechanisms for "cheating" other parties of the interaction (e.g., mimicry or camouflage) in order to achieve their main objective. Within the biological niche, we are dealing with signals that deter or encourage. A deterrent signal warns recipients against becoming the victim of a predator and/or proclaims the signaller's advantage over competitors. An example is aposematism – e.g., the production of vibrant colors that indicate an organism's possession of a deadly poison (Santos et al., 2003) – or long tusks that suggest physical strength. An encouraging signal, meanwhile, is meant to persuade another party to get involved in a relationship. It may be used in relation to mating or the obtaining of food. When forming pairs, a female looks for signals that a male has genes that might allow her offspring to survive (Kirkpatrick, 1982). Peacocks are an example of this: insofar as a large peacock tail is less susceptible to parasites, the bigger its tail, the greater a male's reproductive chances will be (Hamilton and Zuk, 1982). The relationship of sharks and pilot fish constitute an example with regard to the obtaining of food. A shark tolerates pilot fish, which protect it by eating parasites and cleaning its mouth. The shark recognizes pilot fish by characteristic signals in the form of their colors (Magnuson and Godding, 1971).

Practical example 2 – Boston Dynamics and their 'predators'

The American company Boston Dynamics is a pioneer in creating autonomous robots that mimic certain features and abilities of real animals. In one of their experiments, participants expressed confusion and unease caused by a robot that, in many ways, looks and moves like a dog. Interestingly, people watching the robodogs had problems with reading the signals sent by this machine, and they were concerned by the lack of reference points that people look for in live dogs (e.g., the emotions displayed through a dog's eyes or the sounds it makes). In the case of these zoomorphic machines, the lack of certain reference elements turned out to be a deterrent signal that worried the research participants.

In connection with the evolutionary process that has found human beings living in a specific niche, a human being also becomes a sender and receiver of signals. The recognition of signals between humans and other animals is considered paradigmatic and need not be demonstrated here in detail. However, it turns out that in the emerging era of artificial intelligence, signalling also applies to machines, which is suggested by several examples. First, people fear and avoid humanoid machines that do not seem to fully imitate humans (Mori et al., 2012). Thus, imperfect imitation is a deterrent signal. Second, people engage in relationships with machines when they match their aesthetic tastes (Kuntsevich, 2018). In this way, their appearance becomes an encouraging signal. And third, when a machine bears a resemblance to a known predator, humans avoid it (O'Brien, 2018). Thus, its appearance may also be a deterrent signal. A few years ago, in their groundbreaking article, Nass and Moon (2000) indicated that human beings apply similar heuristics to both humans and computers. Their research initiated development of the CASA (Computer Are Social Actors) theory and provided a plethora of examples in favor of its assumptions. Since then, however, the advances made in artificial intelligence and autonomous system are quite considerable. Subsequent generations of humanoids, technomorphs, and androids have emerged that resemble already-living creatures or that seem to suggest completely new groups of entities. Such machines are increasingly gaining autonomy in learning and decision-making processes – and doubts are arising regarding how to classify such autonomous entities that use intelligence and learn. Are they still merely "tools," or do they constitute some sort of para-species? The more interdisciplinary the discussion becomes, the more differences of opinion appear. In this text, we do not propose a definitive answer to this question. Rather, we stress that the reasoning developed by Nass and Moon (2020) in CASA theory may be extended even deeper – crossing the social border and reaching, at least partially, into the context of natural environments. The three signal responses that we noted earlier in this paragraph suggest that humans might behave towards an autonomous machine as if it were a natural subject capable of interaction – constantly seeking signals that might forecast the outcome of such interaction (i.e., antagonistic or non-antagonistic). Using the experimental method, we attempt to show that the *labels* that a machine has been given can serve as a kind of deterrent and/or encouraging signal that human beings rely on when determining whether or not to become involved in interaction.

Practical example 3 – The humanoid Sofia and its ambiguous signals

A remarkable example of a signalling effect was noticed among some people who had the opportunity to personally interact with the humanoid robot Sofia. Clear hesitation and anxiety were noted in the initial interaction. The fact of incomplete mimicking feedback and uncoordinated movements meant that observers did not know what to expect from such a creature. They thus had to look more deeply for answers in the signals sent by Sofia, in order to intuitively understand whether the interactions with this technology would be antagonistic or peaceful. It is believed that in the future, it will also be possible to explain Mori's 'Uncanny Valley' phenomenon, which has been studied since the early 1970s, through an understanding of interspecies interactions.

Country of origin effect (deterrent signal)

The country-of-origin (COO) effect is among the marketing concepts most widely described in the literature: it asserts that people evaluate products according to the country in which they were produced (Roth and Romeo, 1992; Koschate-Fischer et al., 2012). COO labels help customers differentiate between products, especially when they have little information about their features (Lusk et al., 2006); this suggests associations with subconscious signals received in nature. Such an effect also applies to advanced technology (Sevanandee and Damar-Ladkoo, 2018). The more advanced (Ahmed and d'Astous, 2001) and complex (Laroche et al., 2005) a technology is, the more significant the country of origin is to customers who purchase and use it. People appear to cluster countries into "developed" and "developing" ones, preferring high-tech goods from developed countries that are supposed to provide higher quality (Gaedeke, 1973; Mostafa, 2015). This is due to the fact that people feel a fear of technology and attempt to reduce it by making more rational choices. Higgins and Shanklin (1992) proposed four types of such fears: a fear of complexity, fear of obsolescence, fear of being physically harmed, and fear of being socially excluded. It seems, however, that in the era of artificially intelligent autonomous technology, a fifth type is appearing, which is the fear of being replaced by a machine (Modliński, 2021). Translating this to previously used ethological reasoning, a human being may perceive autonomous technology as a competitor and seek signals that can suggest the degree of danger.

People and other animals form herds for various reasons, and there is no clear consensus on why this happens. Some contend that it is animals' attempt to protect themselves (Hamilton, 1971), while others have found that living in groups helps animals to achieve more (Bourke, 2011). In either case, living in groups leads to the emergence of group identification. In the case of human beings, its foundations are shared values, norms, and behavior. When the members of various groups meet each other, they seek signals to assess whether the opposite group will involve them in antagonistic or non-antagonistic interaction. When foreigners appear, they must meet specific criteria to become included in the group (e.g., by receiving the right to vote in elections). One of these is eliminating former affiliations (Blais et al., 2001).

Practical example 4 – Huawei and its 'deterrent signals'

The forms of government possessed by countries and their involvement in international conflicts significantly influence the perception of technology. One of the most notable examples is the case of the Chinese company Huawei, whose technology has raised concerns in the United States over reports of its use in espionage. In many Western countries, China is seen as an authoritarian country that uses technology to track citizens. It is clearly noted that this belief is beginning to affect the perception of Chinese technology. In other words, while the technology itself appears to be deprived of nationality, the country of production seems to have a strong influence on the collective imagination.

If – as supposed in the previous paragraphs – people perceive autonomous technology in the natural-social context, then they should be less inclined to give it autonomy in decision-making (i.e., a privilege of being part of their own group) when such technology sends signals about its origins (through possession of a label indicating its place of production) that suggest that it belongs to a different social group (i.e., a foreign country). That is, we suppose that in the case of an autonomous machine, a label with a country of origin automatically ascribes such an object to an already existing, socio-political picture; this serves as a deterrent signal that discourages human beings from empowering it. For this reason, the following hypothesis may be proposed:

H1a: People have a stronger intention to allow autonomous office assistants to make independent decisions when the assistants' country of origin is unknown than when it is known.

Safety certification (encouraging signal)

In the era of stakeholder empowerment, consumers have greater access to information about a company, its particular offer, alternatives in the market, and other customers' experiences. In accessing such data, they are actively seeking information that they need to make a purchase. Insofar as a "certificate" is a signal sent by the certifying entity that an object meets certain criteria and possesses certain qualities (Kim and Kwon, 2015), companies may apply for one and display it to customers in the form of labels. This trend is particularly evident when it comes to eco-labelling and innovation labelling. Eco-labels are signals that provide clear information to customers that a product meets certain standards of sustainability that correspond with customers' values (Sörqvist et al. l., 2015). The innovation labels used in some countries indicate that a particular company has a reliable technological background and should continue to develop in an above-average manner the upcoming years (Kim et al., 2020).

The high-tech industry is sensitive to labeling, due to the fact that the greater the uncertainty regarding a type of offered product, the stronger the certification effect (Puri, 1996; Kim and Kwon, 2015). Current research shows that people may display higher trust in AI if the device manifesting it possesses a certificate (Bedué and Fritzsche, 2021). Moreover, announcing certification correlates positively with abnormal market value creation and greater-than-average market returns (Deane et al. l., 2019), which suggests that this label fulfills its market function.

As human beings apply similar heuristics to robots and other humans (Nass and Moon, 2000), the possession of certificates by a human employee and autonomous robot may have similar outcomes. When it comes to people, certificates emphasize their skills and competencies. In high-tech businesses, such individuals have greater chances of being selected by a company during the recruitment process (Félix Rodríguez et al. l., 2011), even if experience is valued the most. As companies prefer to hire already competent employees than to invest in employees' education from scratch (Toh et al., 2008), recruiting and maintaining a person possessing a certificate may reduce the risk linked with selection of unqualified candidates. It suggests that a certificate may serve as an encouraging signal for IT recruiters and increase the chances of being incorporated into the organizational community.

Practical example 5 – Greenguard, EU Energy Label and their meanings

People routinely look for certificates when choosing high-tech products. This is evidenced by the existence of over 100 labels that, through their symbols, certify that specific standards and values important for users are being fulfilled. The flagship examples of certification in high-tech industries include GREENGUARD (indicating low chemical emission) and the EU Energy Label (indicating energy-efficiency class). The Edelman 2018 Earned Brand report clearly demonstrates that there is a growing number of people considering certification when choosing new technologies; this is due to the complex language of technological specifications that average users do not understand. A specific certification mark (like GREENGUARD) is a simplified signal intended to give the user a sense of rational choice.

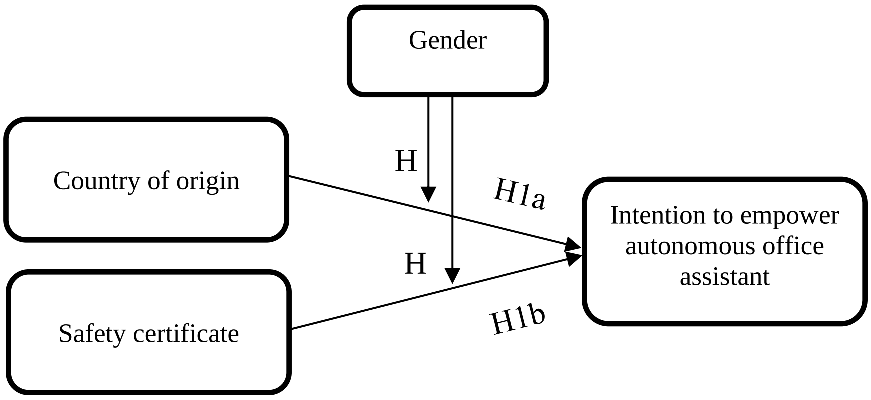
As it turns out that the primary concern in the case of autonomous technology is perceived risk and fear, a certificate proving that such technology is safe should thus serve as an encouraging signal that contributes to greater acceptance of the technology. Thus, we supposed that:

H1b: People have a greater intention of allowing autonomous office assistants to make independent decisions if the assistants possess a safety certificate than if they lack such a certificate.

Gender and the label effect

People attach different importance to the signals they receive, depending on gender. Human males are generally greater risk-takers than females (Turner and McClure, 2003), and this correlation occurs regardless of culture (Zinkhan and Karande, 1991). Females are proven to be more risk-averse, especially when it comes to financial decisions (Suzuki and Avellaneda, 2017) and managing households (Jianakoplos and Bernasek, 1998). Some research suggests that males more often ignore the signals that they receive, for example, when driving a car or engaging in high-risk behaviors (Parker et al., 1995). Females are more anxious about autonomous technology, reporting greater security concerns (Acheampong and Cugurullo, 2019). Males, on the other hand, are more likely to be gadgeteers who use new technology to impress those in their environment, increase their social status, and attract the interest of females (Hrdy, 1980; Wood and Hoeffler, 2013). Such differences may have both cultural and natural reasons. The former involves differences in attitudes and behaviors that occur due to cultural norms imposed on the individual by society (Diamond, 2002). The latter refers to the evolutionary roots of sex differences (Geary, 2021), which suggest that females of a given species are generally more cautious and risk-averse than males, as they bear higher costs than males in reproductive processes (Trivers, 1972). Taking into account that earlier research, we presume that females will be more sensitive to signals than males; we thus proposed the following hypothesis:

H2: Gender moderates the "label effect" so that females have a greater intention to allow autonomous office assistant to make independent decisions if they do not know the country of origin but a safety certificate is provided, whereas for males, neither of these labels significantly influences such intention.



Picture 1. Conceptual model.

METHOD

Research design

A 2×4 (certificate × country-of-origin) between-subject online experiment was designed. To test the proposed hypotheses, two independent variables were manipulated in the study. The first was the certificate of safety. In the experimental group, it was stated that the autonomous office assistant (AOA) technology had been granted a certificate of safety called "Technosafe," while in the control group there was no information about any certificate. The second independent variable manipulated in the experiment was country of origin. In the control group, no information was provided about country of origin, while in three experimental groups the country of origin was provided; it was China (Ex_1), the USA (Ex_2), and Russia (Ex_3), respectively. Equal numbers of participants were assigned to each of eight experimental cells. This research complied with the American Psychological Association Code of Ethics and (to the extent applicable) was approved by the Institutional Review Board for the CAICR Research Center. Informed consent was obtained from each participant.

Stimuli and pre-tests

The experimental stimuli were a poster promoting an autonomous office assistant with the fictitious name "DX383." We provided no brand name, to avoid transposing already existing attitudes people have towards a company to technology that they are seeing for the very first time. The poster was made by professional poster designers with neutral coloring. There were two photos on the poster, of a computer and modern buildings. At the top middle was the tagline "DX383 is able to make independent decisions… if you just agree." Below was information about the system's functionalities: arranging meetings, finding and storing documents, paying invoices directly from a user's bank account, responding to e-mails, reacting to voice commands, and making real-time conversation with a user. The poster for each experimental cell was based on the same template. There were no differences regarding color, name, photos, size, or functionalities across experimental conditions. In the experimental groups, there appeared in bold the phrases "Made in …" and/or "This technology has been granted the International Safety Certificate TECHNOSAFE."

A pre-test and attention check were employed to control the experimental conditions. The pre-test was made three weeks before the final study to check whether the color or the AOA's name evoked any associations with recognizable brands. We invited 20 students and showed them the poster, asking three questions: (1) do you know this technology? (option: yes/no); (2) who might be the producer of this technology? (open question); and (3) what is unique about this technology? (open question). None of the respondents had heard of the DX383 autonomous assistant before. In the case of the second question, the most common answer was "I don't know" (16 people); other responses included "Elon Musk" (2 people), "Google," and "George Orwell." In the case of the third question, 19 people noted the narrative that the autonomous assistant makes decisions by itself, while one person did not see anything unique in the technology. We thus concluded that the material was sufficiently neutral and did not suggest any associations that could disrupt the experiment. The attention check took place during the experiment. First, the participants were exposed to the poster. Then, depending on the group, they were asked to answer a few attention-focusing questions. Their distribution across experimental cells is noted in the table below. We intentionally did not ask about certification and/or country of origin in some groups, to avoid participants seeking information that does not exist. The questions were designed to concentrate the attention of participants on specific features of the AOA (i.e., country/certificate).

Table 1. Questions used for an attention check during the experimental study (yes = question was asked; no = question was not asked).

Cell number	Cell description	Does autonomous assistant make independent decisions?	Does this technology possess any safety certification?	Is it known in which country this technology was made?	Number of research participant who did not respond to the question as intended
0	No country No certificate	Yes	No	No	1
1	No country Certificate	Yes	Yes	No	0
2	China No certificate	Yes	No	Yes	1
3	China Certificate	Yes	Yes	Yes	0
4	USA No certificate	Yes	No	Yes	0
5	USA Certificate	Yes	Yes	Yes	2
6	Russia No certificate	Yes	No	Yes	1
7	Russia Certificate	Yes	Yes	Yes	1

Experimental procedure and participants

Two hundred and ninety-five people took part in the experimental study and were randomly assigned to one of eight experimental cells. Fourteen people did not complete the questionnaire, and another six were excluded as they did not pass the attention check. Thus, the final sample consisted of 274 participants (54% females). The youngest person in the group was 18, while the oldest one was 82 (M_{age} = 28.09; SD_{age} = 13.49). Participants were recruited via a social media platform and represented different nationalities. There was a predominance of people under 40 years old. Data was collected during two full days (48 hours) and each IP address had only one opportunity to participate in the study. All participants received the poster and set of questions. There was no time limit to complete the questionnaire.

Measures

There were three dependent variables measured in the study. First, the intention to allow a machine to independently make decisions was measured on a 1-item, seven-point scale borrowed from previous experiments on techno-empowerment (Modliński, 2021). Trust in technology and perceived risk were control variables measured respectively by a 9-item, seven-point scale (α = .87) borrowed from McKnight et al. (2011) and 4-item, seven-point scale (α = .88) of Laroche et al. (2005). Data on gender and age were collected.

RESULTS

To test H1a, we used the U test of Mann-Whitney, due to the fact that the experimental groups were not equal. In one group (control) no country was provided, while in three groups the country was known (USA, China, Russia). The results show that the differences between the control and experimental groups were significant (Z = -2.024; $p < .05$). Mean ranks in the control group was M_{Con} = 153.81, whereas in an experimental group it was M_{Exp} = 131.90. Also found were significant differences in trust (Z = -2.349; $p < .05$; M_{Con} = 156.68; M_{Exp} = 130.92). It may thus be concluded that people have higher trust and intention to allow an AOA to make independent decisions if its country of origin is unknown rather than known, which supports H1a. Moreover, we found no significant differences between the three experimental groups – which suggests that whatever its country of origin, people have similar trust and intention to empower an AOA.

To test H1b, we ran the student t test for independent samples. There were differences between the control and experimental groups in both trust (t = -2.184; df = 272; $p < .05$) and intention to empower the AOA (t = -2.352; df = 270; $p < .05$). In the group where a safety certificate was provided, trust (M_{Cert} = 5.21; SD_{Cert} = 1.15) and intention to empower the AOA (M_{Cert} = 3.67; SD_{Cert} = 1.82) were higher than in the group where no safety certification was mentioned (trust: M_{NoCer} = 4.91; SD_{NoCer} = 1.16; intention: M_{NoCer} = 3.17; SD_{NoCer} = 1.71), which supports H1b.

To test H2, we split the sample by gender and made two tests: an arithmetic means and independent U test of Mann-Whitney. First, we analyzed the results concerning country of origin. In the group of males, the differences between experimental groups were not statistically significant, which suggests males have similar intention to empower an AOA, regardless of whether the country is known or unknown. In the group of females, however, such differences are statistically significant (Z = -2.398; $p < .05$), as presented in Table 2. Females had a greater intention to allow the autonomous assistant to make independent decisions when they did not know in which country it was made (R_{NoCon} = 88.19) than when the country was specified (R_{Con} = 69.43).

Table 2. Intention to empower an AOA dependent on country among males and females.

Gender	Group	Mean	Rank	p	Z
Male	Country	3.3125	62.96	.762	-.302
	No country	3.4333	65.23		
Female	Country	3.2778	69.43	.016	-2.398
	No country	4.0250	88.19		

Second, we analyzed the results concerning the safety certificate. Once again, the differences among males were not statistically significant, which implies that a safety certificate does not influence their intention to empower an AOA. In females, the differences were statistically significant ($Z = -2.251$; $p < .05$); they declared a greater intention to empower an AOA if it had a safety certificate (R_{Cert} = 82.42) than if it lacked such a label (R_{NoCer} = 66.79), which supports H2. The exact data are presented in Table 3.

Table 3. Intention to empower an AOA dependent on safety certification among males and females.

Gender	Group	Mean	Rank	p	Z
Male	Certificate	3.48	66.12	.414	-.817
	No certificate	3.21	60.88		
Female	Certificate	3.84	82.42	.024	-2.251
	No certificate	3.13	66.79		

DISCUSSION

The article offers three major contributions to previous research on autonomous technology's acceptance. First of all, the article confirms previous reports that the country of origin of a technology affects its acceptance and trust (Gaedeke, 1973; Mostafa, 2015). However, such earlier research focused on differences between particular countries. Our contribution is the discovery that in the case of autonomous assistants, it is better not to emphasize the fact that such technology possesses a country of production at all, if one wants to increase the confidence in its operation. In the case of the experimental groups in which the AOA's country of origin was indicated, it is worth noting that the USA, China, and Russia are not fictional, little-known, or "neutral" countries towards which participants were unlikely to have developed any pre-existing attitudes. Rather, these countries are all prominent geopolitical actors towards which many persons might reasonably be expected to already possess a range of (potentially strong) positive or negative sentiments. Interestingly, this study's results suggest that with regard to developing an intention to empower an autonomous system to make independent decisions, indicating the identity of the *particular country* in which the AOA was produced has less of an impact on persons' intention to empower it than the mere fact that they are being generically reminded of the fact that it must have been produced in *some* foreign country *somewhere*. The interplay of such influences might be further tested in future experiments by, for example, studying differences in the intention to empower between participants who are told that an AOA has been produced in some foreign country and those who are told that it has been produced in their own country – and who, from an ethological perspective, might thus potentially discern a signal that the device is from “their own” group and therefore likely to engage in non-antagonistic interaction. Second, our study confirms previous results that safety certification can be an important factor affecting the trust in technology (Kim and Kwon, 2015; Bedué and Fritzsche, 2021). However, this paper extends a previous research area to include autonomous assistants. The results clearly suggest that it pays for companies offering such technology to invest in the certification process.

Taken as a whole, this study’s findings suggest that as human beings develop increasingly sophisticated artificially intelligent technologies that are capable of making autonomous decisions and engaging with us as intelligent social actors, the manner in which we interact with such technological marvels will, in many ways, inevitably be governed by cultural factors that emerged within human societies thousands of years ago, as well as by even more fundamental biologically based traits and behaviors whose evolution can be traced back millions of years. Rather than representing an unprecedented and qualitatively novel manner of engaging with other entities, our future interactions with autonomous technologies may ultimately just be the latest manifestation of those timeless forms of antagonistic and non-antagonistic interaction through which we engage with other human beings and animals – and through which other species of animals interact with one another. These results significantly contribute to extending the theory of Nass and Moon (2000) by demonstrating that in order to fully understand the human attitudes towards autonomous technology, we cannot overlook the evolutionary and ethological groundings of interactions that have been developing for ages between natural actors. Unfortunately, these aspects are still widely underestimated by persons designing new technologies, which can be seen to impede development of the concept of human-oriented technology.

LIMITATIONS

Although our study extended the theory of creating human-oriented technology, it also has limitations that should be clearly emphasized. First, a limitation of any experimental study is that its results cannot be generalized to the entire population, and this study was partially conducted under laboratory conditions during the unique circumstances of the COVID19 pandemic. The obtained results should therefore be replicated in the future and included in a broader meta-analytical context. Second, a fictitious brand of autonomous assistants was used in the study, which has both advantages and disadvantages. Proponents of the use of fictitious brands in experimental research emphasize that it makes it possible to avoid combining previous associations with the studied object, thus the effect is ‘cleaner’ and more reliable. Skeptics emphasize that a subject may have limited ability to develop preferences for objects of unfamiliar brands without being able to physically interact with them. Therefore, we recommend replicating the research with existing brands in the future. Third, the study did not control for whether the respondents had known and used autonomous assistants before. Although it is still a little-known technology, there is a chance that some of the respondents have already used it. However, to prevent such differentiation from affecting the results, the respondents were randomly assigned to the experimental groups. Fourth, in the case of one respondent, there was a problem with the operation of the computer the individual was using for the study. Although the hardware problem was successfully resolved, this respondent's results were removed from the total sample to ensure the highest possible reliability of the total outcomes.

CONCLUSION

Attitudes towards autonomous technology may be at least partially explained by observing the natural and social interactions between various agents that occupy a particular ecological niche. Of course, we are not saying that a machine is a "natural" actor; there is no doubt about the fact that it has been artificially created by human beings. However, this study suggests that such an artificial actor may subconsciously be treated like other natural environmental actors. In order to estimate the risks associated with such an artificial agent, human beings spontaneously look for the kinds of signals that have accompanied them through countless years of evolution. If we seek to fully understand human interactions with intelligent machines, it is thus worth referring to interspecies relations.

As this study has found, people have the strongest intention to allow an autonomous office assistant to make independent decisions if its country of origin is unknown but a safety certificate is provided. This is consistent with the fact that a human being seeks signals that suggest the outcome of any future interaction. Signals are also used when it comes to incorporating an agent into (or excluding an agent from) a group. However, gender moderates the "label effect," with females expressing a stronger intention to allow an autonomous office assistant to make independent decisions if they do not know the country of origin but a safety certificate is provided – whereas for males, neither such label significantly influences their intention. This may have roots in both evolutionary and cultural differences between genders.

HIGHLIGHTS

1. A country-of-origin label may deter customers from empowering or using empowered technology.
2. In order to encourage people to adopt it, an autonomous assistant should be presented as something "stateless."
3. A safety certificate serves as an encouraging signal that increases human beings' intention to empower autonomous assistants. For this reason, companies designing autonomous technology should invest in safety certification to increase acceptance of such technology among users. Insofar as the current number of safety certificates available for autonomous technology is extremely limited, new ones should be designed and commercialized.
4. The labelling effect is stronger in females than males, which suggest that companies primarily targeting females should pay greater attention to what signals they are really sending.

REFERENCES

Acheampong, R.A., & Cugurullo, F. (2019). Capturing the behavioural determinants behind the adoption of autonomous vehicles: Conceptual frameworks and measurement models to predict public transport, sharing and ownership trends of self-driving cars, *Transportation Research Part F: Traffic Psychology and Behaviour, 62*, 349-375, https://doi.org/10.1016/j.trf.2019.01.009.

Ahmed, S.A., & d'Astous, A. (2001). Canadian consumers' perceptions of products made in newly industrializing East Asian countries. *International Journal of Commerce and Management*, *11*(1), 54-81.

Akerkar, R. (2019). *Artificial intelligence for business*. Springer: Briefs in Business.

Bedué, P., & Fritzsche, A. (2021). Can we trust AI? An empirical investigation of trust requirements and guide to successful AI adoption. *Journal of Enterprise Information Management*. https://doi.org/10.1108/JEIM-06-2020-0233

Blais, A., Massicotte, L., & Yoshinaka, A. (2001). Deciding who has the right to vote: a comparative analysis of election laws. *Electoral studies*, *20*(1), 41-62.

Borau, S., Otterbring, T., Laporte, S., & Fosso Wamba, S. (2021). The most human bot: Female gendering increases humanness perceptions of bots and acceptance of AI. Psychology & Marketing, 38(7), 1052-1068, https://doi.org/10.1002/mar.21480

Bourke, A.F.G. (2011). *Principles of social evolution*. Oxford University Press, USA.

Brooks, B. (2021). Get ready for self-driving banks, Financial Times, retrieved from: https://www.ft.com/content/c1caca5b-01f7-41be-85a4-3ecb883f2417

Charness, N., Yoon, J. S., Souders, D., Stothart, C., & Yehnert, C. (2018). Predictors of attitudes toward autonomous vehicles: The roles of age, gender, prior knowledge, and personality. *Frontiers in psychology*, *9*, 2589, https://doi.org/10.3389/fpsyg.2018.02589.

Cook, D. J., Augusto, J. C., & Jakkula, V. R. (2009). Ambient intelligence: Technologies, applications, and opportunities. *Pervasive and Mobile Computing*, *5*(4), 277-298.

Daugherty, P. R., & Wilson, H. J. (2018). *Human+ machine: Reimagining work in the age of AI*. Harvard Business Press.

David, P. (2017). Cobots – a helping hand to the healthcare industry, Universal robots, retrieved from: https://www.universal-robots.com/blog/cobots-a-helping-hand-to-the-healthcare-industry/

De Visser, E. J., Monfort, S. S., Goodyear, K., Lu, L., O'Hara, M., Lee, M. R., ... & Krueger, F. (2017). A little anthropomorphism goes a long way: Effects of oxytocin on trust, compliance, and team performance with automated agents. *Human factors*, *59*(1), 116-133.

Deane, J. K., Goldberg, D. M., Rakes, T. R., & Rees, L. P. (2019). The effect of information security certification announcements on the market value of the firm. *Information Technology and Management*, *20*(3), 107-121. https://doi.org/10.1007/s10799-018-00297-3

Diamond, M. (2002). Sex and gender are different: Sexual identity and gender identity are different. *Clinical child psychology and psychiatry*, *7*(3), 320-334.

Elton, Ch. S. (2001). *Animal Ecology*. University of Chicago Press.

Endsley, M. R. (2017). From here to autonomy: lessons learned from human–automation research. *Human factors*, *59*(1), 5-27.

Fogg, B. J. (2002). Persuasive technology: Using computers to change what we think and do. *Ubiquity*, *2002*(December), 2.

Gabrys, B. (Ed.). (2006). *Knowledge-Based Intelligent Information and Engineering Systems: 10th International Conference, KES 2006, Bournemouth, UK, October 9-11 2006, Proceedings, Part II* (Vol. 4252). Springer.

Gaedeke, R. (1973). Consumer attitudes toward products made in developing countries. *Journal of Retailing*, *49*(2), 13-24.

Galina, S., & Zarina, S. (2019). Development of smart technology for complex objects prediction and control on the basis of a distributed control system and an artificial immune systems approach. *Advances in Science, Technology and Engineering Systems, 4*(3), 75-87.

Geary, D. C. (2010). *Male, female: The evolution of human sex differences*. American Psychological Association.

Gilbert, J., & Oladi, R. (2021). Labor-eliminating technical change in a developing economy. *International Journal of Economic Theory*, *17*(1), 88-100.

Grinnell, J. (1917). The niche-relationships of the California Thrasher. *The Auk*, *34*(4), 427-433. https://doi.org/10.2307/4072271.

Hamilton, W. D. (1971). Geometry for the selfish herd. *Journal of theoretical Biology*, *31*(2), 295-311.

Hamilton, W. D., & Zuk, M. (1982). Heritable true fitness and bright birds: a role for parasites?. *Science*, *218*(4570), 384-387.

Hancock, P. A., Billings, D. R., Schaefer, K. E., Chen, J. Y., De Visser, E. J., & Parasuraman, R. (2011). A meta-analysis of factors affecting trust in human-robot interaction. *Human factors*, *53*(5), 517-527.

Higgins, S. H., & Shanklin, W. L. (1992). Seeking Mass Market Acceptance for High-Technology Consumer. *The Journal of Consumer Marketing*, *9*(1), 5-14.

Hrdy, S. B. (1980). *The langurs of Abu: female and male strategies of reproduction*. Harvard University Press.

Hudson, J., Orviska, M., & Hunady, J. (2019). People's attitudes to autonomous vehicles. *Transportation research part A: policy and practice*, *121*, 164-176, https://doi.org/10.1016/j.tra.2018.08.018.

Jianakoplos, N. A., & Bernasek, A. (1998). Are women more risk averse?. *Economic inquiry*, *36*(4), 620-630.

Jones, S. E. (2013). *Against technology: From the Luddites to neo-Luddism*. Routledge.

Kaplan, A., & Haenlein, M. (2019). Siri, Siri, in my hand: Who's the fairest in the land? On the interpretations, illustrations, and implications of artificial intelligence. *Business Horizons*, *62*(1), 15-25, https://doi.org/10.1016/j.bushor.2018.08.004

Kim, K., Choe, C., & Lee, D. (2020). Overlapping certification and technical efficiency of ICT convergence companies in South Korea. *Science and Public Policy*, *47*(4), 514-524, https://doi.org/10.1093/scipol/scaa031

Kim, N., & Kwon, K. M. (2015). Certification benefits in high-tech industry: Evidence from supply contracts in the Korean market. *Emerging Markets Finance and Trade, 51*(5), 1001-1020.

Kirkpatrick, M. (1982). Sexual selection and the evolution of female choice. *Evolution*, *36*(1), 1-12. doi:10.2307/2407961

Koschate-Fischer, N., Diamantopoulos, A., & Oldenkotte, K. (2012). Are consumers really willing to pay more for a favorable country image? A study of country-of-origin effects on willingness to pay. *Journal of International Marketing*, *20*(1), 19-41.

Krebs, C. J. (2008). *Ecology: The experimental analysis of distribution and abundance*. Person Editorial House.

Kuntsevich, R. (2018). *AI and sex toys*. Retrieved from https://dashbouquet.com/blog/artificial-intelligence/sex-toys-and-artificial-intelligence

Laroche, M., Yang, Z., McDougall, G. H., & Bergeron, J. (2005). Internet versus bricks-and-mortar retailers: An investigation into intangibility and its consequences. *Journal of retailing*, *81*(4), 251-267.

Lusk, J. L., Brown, J., Mark, T., Proseku, I., Thompson, R., & Welsh, J. (2006). Consumer behavior, public policy, and country-of-origin labeling. *Applied Economic Perspectives and Policy*, *28*(2), 284-292.

Lyons, J. B., Vo, T., Wynne, K. T., Mahoney, S., Nam, C. S., & Gallimore, D. (2021). Trusting autonomous security robots: the role of reliability and stated social intent. *Human factors*, *63*(4), 603-618.

Magnuson, J. J., & Gooding, R. M. (1971). Color patterns of pilotfish (Naucrates ductor) and their possible significance. *Copeia*, *1971*(2), 314-316. https://doi.org/10.2307/1442834

Makridakis, S. (2017). The forthcoming Artificial Intelligence (AI) revolution: Its impact on society and firms. *Futures*, *90*, 46-60.

Maurtua, I., Ibarguren, A., Kildal, J., Susperregi, L., & Sierra, B. (2017). Human–robot collaboration in industrial applications: Safety, interaction and trust. *International Journal of Advanced Robotic Systems*, *14*(4), 1729881417716010. https://doi.org/10.1177/1729881417716010.

McAfee, A., & Brynjolfsson, E. (2017). *Machine, platform, crowd: Harnessing our digital future*. WW Norton & Company.

Mcknight, D. H., Carter, M., Thatcher, J. B., & Clay, P. F. (2011). Trust in a specific technology: An investigation of its components and measures. *ACM Transactions on management information systems (TMIS)*, *2*(2), 1-25. https://doi.org/10.1145/1985347.1985353

Michel, L., Nicolas, P., Louise, A. H., & Mehdi, M. (2005). The influence of country image structure on consumer evaluations of foreign products. *International Marketing Review, 22*(1), 96-115.

Modliński, A. (2021a). *The coming of autonomous machines. Multi-method research on the limits of techno-empowerment*.

Modlinski, A., & Pinto, L. M. (2020). Managing substitutive and complementary technologies in cultural institutions: Market/mission perspectives. *Management: Journal of Contemporary Management Issues*, *25*(Special issue), 1-10.

Modliński, A., Gwiaździński, E., & Karpińska-Krakowiak, M. (2021). To target the (pr)opponents of autonomous vehicles. The effects of gender and religiosity on attitudes towards autonomous vehicles.

Modlinski, A., Skworonski, D. (2021). Robopowers? The phenomenon of technoempowerment in the socio-organizational context.

Mori, M., MacDorman, K. F., & Kageki, N. (2012). The uncanny valley [from the field]. *IEEE Robotics & Automation Magazine*, *19*(2), 98-100.

Mostafa, R. H. (2015). The impact of country of origin and country of manufacture of a brand on overall brand equity. *International Journal of Marketing Studies*, *7*(2), 70.

Nappi, I., & de Campos Ribeiro, G. (2019). Internet of Things technology applications in the workplace environment: a critical review. *Journal of Corporate Real Estate*, *22*(1), 71-90.

Nass, C., & Moon, Y. (2000). Machines and mindlessness: Social responses to computers. *Journal of social issues*, *56*(1), 81-103. https://doi.org/10.1111/0022-4537.00153.

O'brien, M. (2018). Boston Dynamics' scary robot videos: Are they for real?, Phys.org, retrieved from: https://phys.org/news/2018-06-boston-dynamics-scary-robot-videos.html

Parker, D., Reason, J. T., Manstead, A. S., & Stradling, S. G. (1995). Driving errors, driving violations and accident involvement. *Ergonomics*, *38*(5), 1036-1048.

Pelau, C., Dabija, D. C., & Ene, I. (2021). What makes an AI device human-like? The role of interaction quality, empathy and perceived psychological anthropomorphic characteristics in the acceptance of artificial intelligence in the service industry. *Computers in Human Behavior*, *122*, 106855. https://doi.org/10.1016/j.chb.2021.106855

Pettigrew, S., Fritschi, L., & Norman, R. (2018). The potential implications of autonomous vehicles in and around the workplace. *International journal of environmental research and public health*, *15*(9), 1876.

Puri, M. (1996). Commercial banks in investment banking conflict of interest or certification role?. *Journal of Financial Economics, 40*(3), 373-401.

Rodríguez, O. F., Fernández, F., & Torres, R. S. (2011). Impact of information technology certifications in Puerto Rico. *Management Research, 9*(2), 137–153.

Roth, M. S., & Romeo, J. B. (1992). Matching product catgeory and country image perceptions: A framework for managing country-of-origin effects. *Journal of international business studies*, *23*(3), 477-497.

Santos, J. C., Coloma, L. A., & Cannatella, D. C. (2003). Multiple, recurring origins of aposematism and diet specialization in poison frogs. *Proceedings of the National Academy of Sciences*, *100*(22), 12792-12797. https://doi.org/10.1073/pnas.2133521100

Schaefer, K. E., Chen, J. Y., Szalma, J. L., & Hancock, P. A. (2016). A meta-analysis of factors influencing the development of trust in automation: Implications for understanding autonomy in future systems. *Human factors*, *58*(3), 377-400.

Sevanandee, B., & Damar-Ladkoo, A. (2018). Country-of-Origin effects on consumer buying behaviours. A Case of Mobile Phones. *Studies in Business and Economics*, *13*(2), 179–201.

Sörqvist, P., Haga, A., Langeborg, L., Holmgren, M., Wallinder, M., Nöstl, A., ... & Marsh, J. E. (2015). The green halo: Mechanisms and limits of the eco-label effect. *Food quality and preference*, *43*, 1-9.

Suzuki, K., & Avellaneda, C. N. (2018). Women and risk-taking behaviour in local public finance. *Public Management Review*, *20*(12), 1741-1767. doi:10.1080/14719037.2017.1412118

Tay, B. T., Low, S. C., Ko, K. H., & Park, T. (2016). Types of humor that robots can play. *Computers in Human Behavior*, *60*, 19-28.

Tennant, C., Stares, S., & Howard, S. (2019). Public discomfort at the prospect of autonomous vehicles: Building on previous surveys to measure attitudes in 11 countries. *Transportation research part F: traffic psychology and behaviour*, *64*, 98-118, https://doi.org/10.1016/j.trf.2019.04.017.

Toh, S. M., Morgeson, F. P., & Campion, M. A. (2008). Human resource configurations: investigating fit with the organizational context. *Journal of Applied Psychology*, *93*(4), 864.

Trivers, R. L. (2017). *Parental investment and sexual selection* (pp. 136-179). Routledge.

Turner, C., & McClure, R. (2003). Age and gender differences in risk-taking behaviour as an explanation for high incidence of motor vehicle crashes as a driver in young males. *Injury control and safety promotion*, *10*(3), 123-130.

Waytz, A., Heafner, J., & Epley, N. (2014). The mind in the machine: Anthropomorphism increases trust in an autonomous vehicle. *Journal of Experimental Social Psychology*, *52*, 113-117.

Winn, Z. (2020). A human-machine collaboration to defend against cyberattacks. Massachusetts Institute of Technology, retrieved from https://news.mit.edu/ 2020/patternex-machine-learning-cybersecurity-0221

Wood, S., & Hoeffler, S. (2013). Looking Innovative: Exploring the Role of Impression Management in High-Tech Product Adoption and Use. *Journal of Product Innovation Management*, *30*(6), 1254-1270.

Xu, X., & Fan, C. K. (2019). Autonomous vehicles, risk perceptions and insurance demand: An individual survey in China. *Transportation research part A: Policy and practice*, *124*, 549-556.

Authors' Note

All correspondence should be addressed to
Artur Modliński
University of Łódź, Faculty of Management, Department of Management,
Matejki 22/26, 90-137 Łódź, Poland
artur.modlinski@uni.lodz.pl

Human Technology
ISSN 1795-6889
https://ht.csr-pub.eu

APPENDIX

Appendix 1 – Stimuli

Control group: Certificate: not provided; Country: not provided

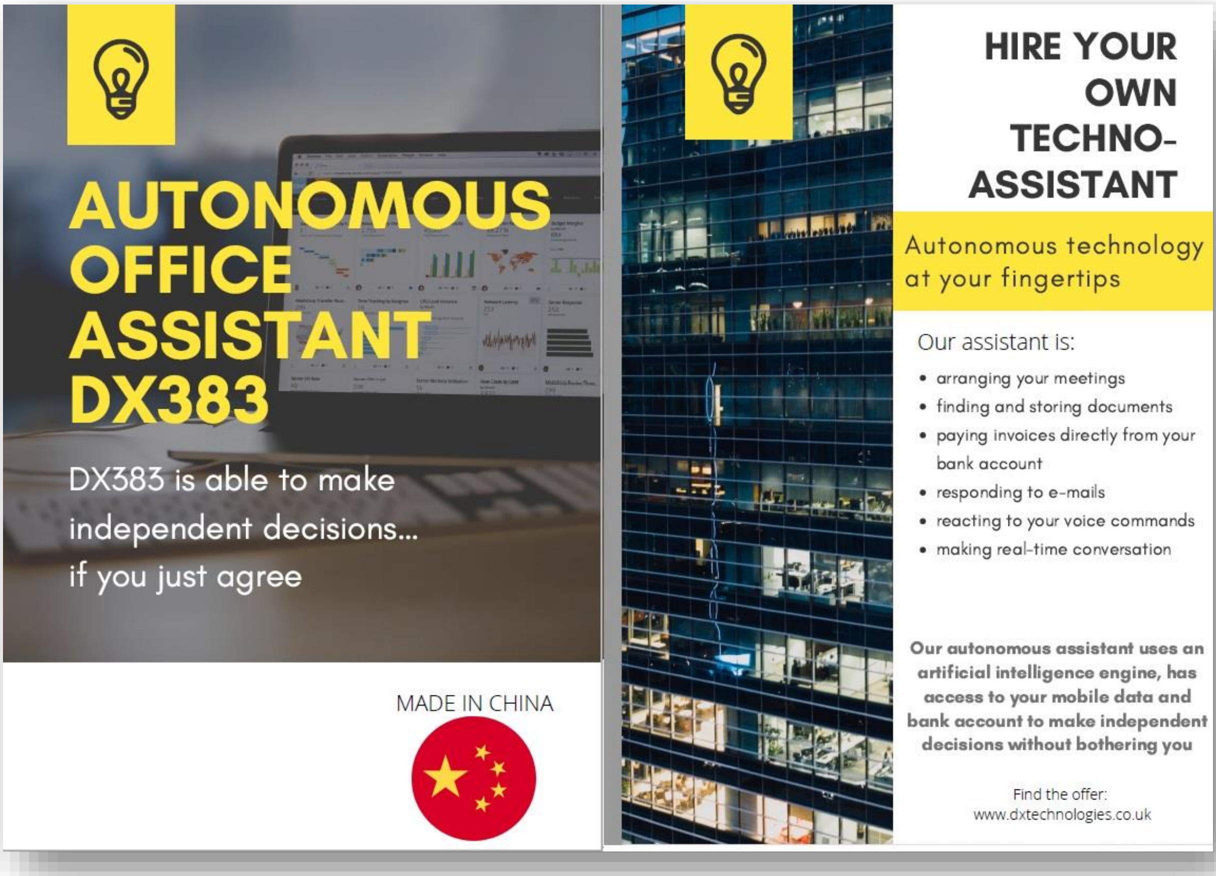
Experimental group: Certificate: provided; Country: not provided

Experimental group: Certificate: provided; Country: USA

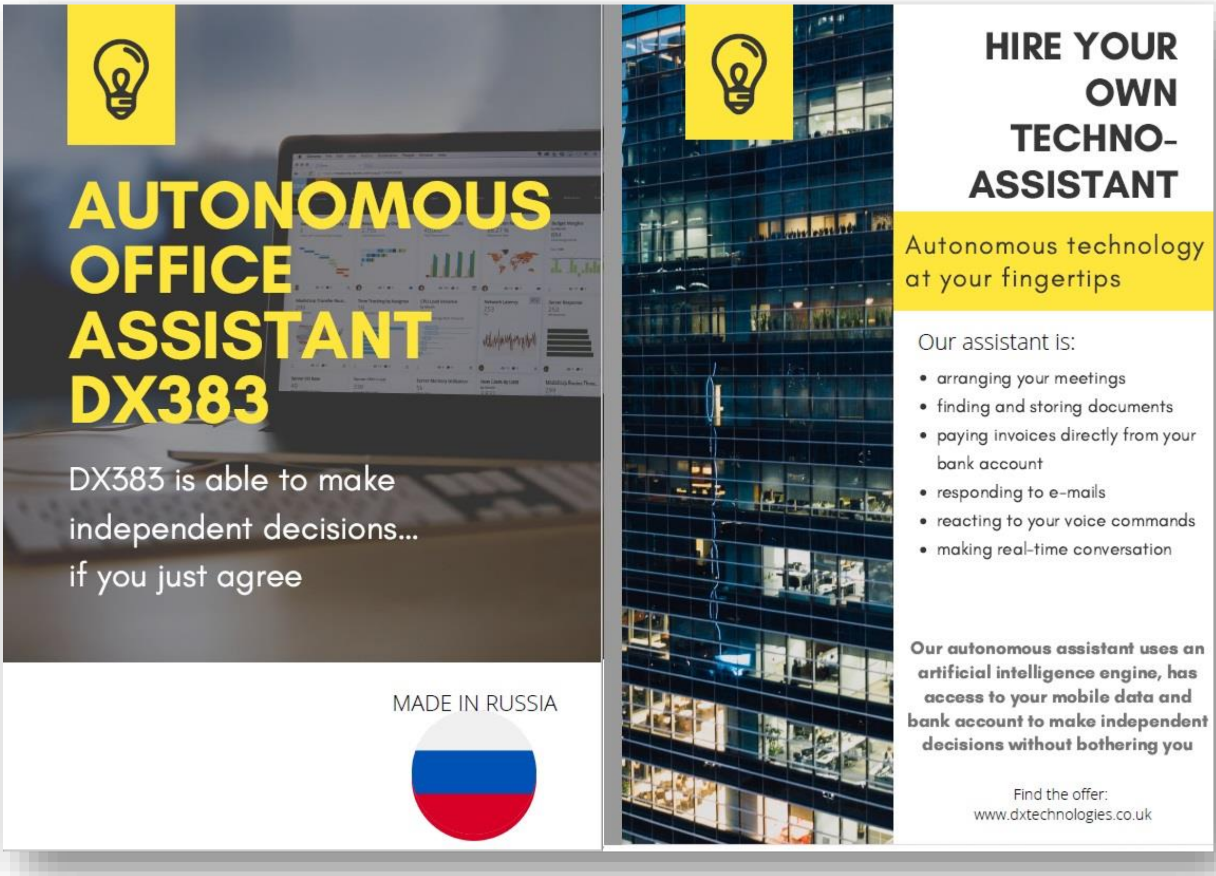
Experimental group: Certificate: provided; Country: China

Experimental group: Certificate: provided; Country: Russia

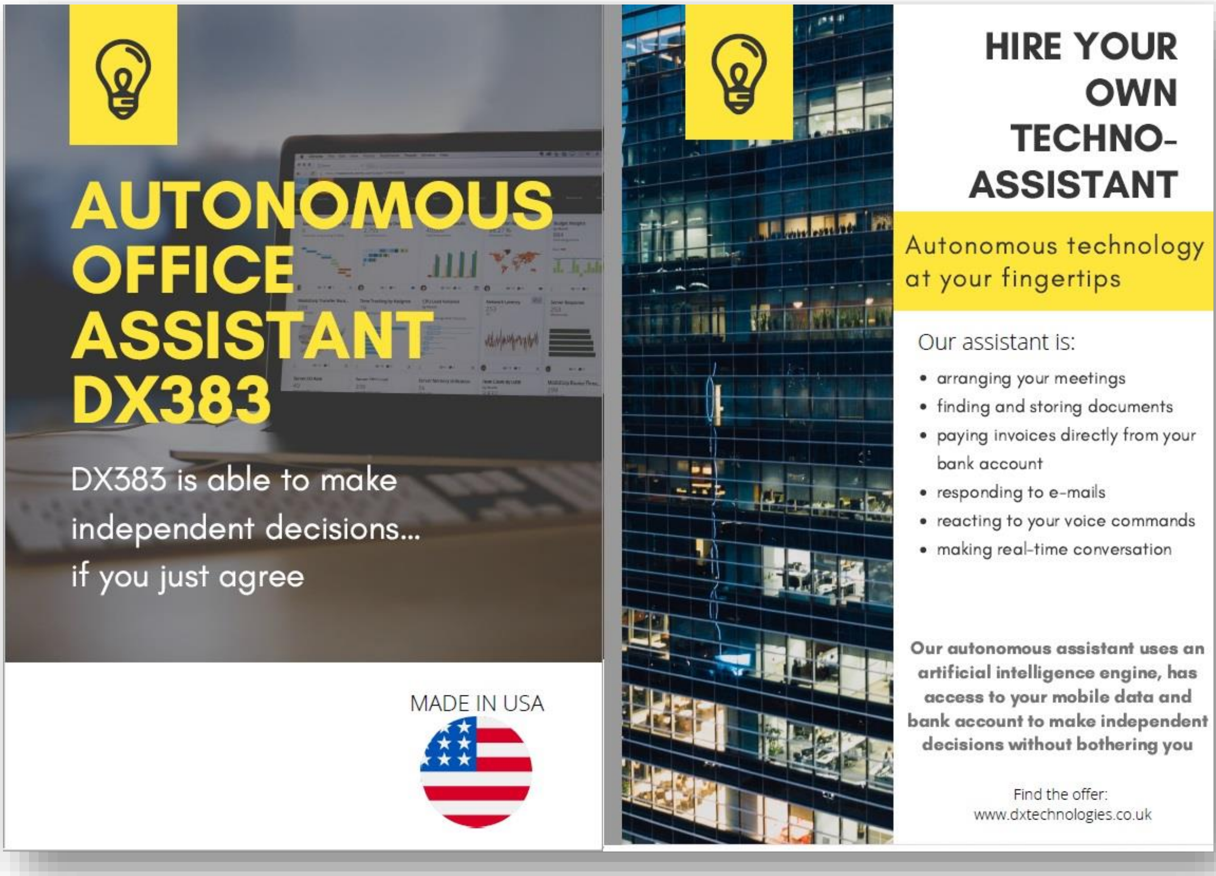
Experimental group: Certificate: not provided; Country: China



Experimental group: Certificate: not provided; Country: Russia



Experimental group: Certificate: not provided; Country: USA



Human Technology

https://ht.csr-pub.eu/

office@csr-pub.eu

Submissions:
https://ht.csr-pub.eu/index.php/ht/about/submissions