Published by the Centre of Sociological Research, Poland

ISSN: 1795-6889

Human TECHNOLOGY

Volume 18, Number 3, December 2022

Kristiina Korjonen-Kuusipuro
Adam Wojciechowski
Editors in Chief

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

Human TECHNOLOGY

Volume 18, Number 3, December 2022

DOI: https://doi.org/10.14254/1795-6889.2022.18-3

Contents

Original Articles

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 18(3), December 2022, 209-212

From the Editors-in-Chief

REHABILITATION IN DIGITAL ENVIRONMENTS – BIOPHYSIOLOGICALLY MOTIVATED GAMIFICATION

Adam Wojciechowski
Lodz University of Technology
Poland
ORCID 0000-0003-3786-7225

Kristiina Korjonen-Kuusipuro
South-Eastern Finland University of Applied Sciences
Finland
ORCID 0000-0002-8528-0237

Abstract: *Nowadays, the process of cognitive or motor rehabilitation is mostly implemented in a traditional form. Paper-pencil cognitive exercises or physical exercises with instruments still dominate over digital environments. However, they require constant supervision by professionals, whose availability is relatively decreasing in an ageing society. Lack of supervision, in turn, results in a loss of motivation to exercise or, at the very least, ineffective, sometimes incorrect, exercise. In addition, traditional rehabilitation mechanisms are often repetitive and tedious. Sometimes a lack of supervision or routine results in a failure to adapt the challenges to the user's current needs.*
Digital environments and modern technology have much to offer in this regard. One aspect is gamification mechanisms, which work well in video games and allow players to be engaged for hours in challenges of modulated difficulty. Another aspect is the rapidly developing biosensors and tracking systems that allow the user's activity and biophysiological parameters to be monitored in real time. However, the combination of the benefits of technology and gamification stimulus mechanisms must be done in strict accordance with the user's capabilities in order to make the challenges constructive rather than destructive for the user's body and mental conditions. Ongoing monitoring of effort and mental workload and their synchronization with fatigue in the digital environment, supported by motivational gamification mechanisms, form the foundation of the correct and controlled exercises and rehabilitation.

Keywords: *rehabilitation, gamification, biofeedback, digital environment, human-technology.*

DOI: https://doi.org/10.14254/1795-6889.2022.18-3.1

Physical Activity

In the field of physical rehabilitation, a number of parameters can be monitored, and very different goals can be set. People with limited mobility aim to improve the range of movement of their limbs, or to better coordinate their movements, hence monitoring the current range of movement, or its trajectory/dynamics, can be an interface input parameter on which the achievement of goals depends. People with limited performance should perform movement exercises to improve it. Each age, for example, has its own recommended heart rate (ACSM 2000). If we treat the current heart rate as an input signal and make the task scenario dependent on it, this creates a fitness-dependent control mechanism. The analogy is with balance control.

Unfortunately, most of existing digital physical-rehabilitation games (exergames) effects and accompanying conditions of a series of exercises are usually assessed after the exercises (ex-post), resulting in bias (Furukado et al. 2021) and uncertainty of exercise. We are more often dealing with an analysis of the effects of exercise than with a monitored and personalized challenge (Ismail et al. 2022). Exergame interfaces are focused rather on threshold values or hardcoded patterns detection. An exergame gameplay balance correlated with physical challenges is rare and it should be kept in mind that very often the motivation to perform can arise from other circumstances (e.g. team competition, loss aversion, others) (Niforatos et al. 2021). It should also be taken into account that the actual strain on the body is usually different from the fatigue perceived by the individual (Stewart et al. 2022).

Exemplary, in Battussi et al (2007) level of difficulty is automatically adjusted if the system determines that the user should exert more or less physical effort maintaining users heart rate within its target zone. Masuko et al. (2006) proposed a boxing game in which the effort was adjusted so that the heart rate oscillated within the recommended range. Stach et al. (2009) proposed a game in which the heart rhythm was scaled so that people with different heart performance had comparable conditions to compete in a truck race controlled by a stationary bicycle. Hagen et al. (2016) recognized the problem of better balancing activity and rest in exergame exercises, but they solved this discreetly by varying the gameplay scenarios according to user fatigue. The problem is discussed at considerable depth in Martin-Niedecken's (2021) doctoral dissertation, only reinforcing the constant need for a conscious and tailored combination of physical exercise with a digital experience scenario.

Mental Workload

An important biophysiological aspect is Mental Workload (MWL). Cognitive load is a limited resource (Gomez 2021) hence the simultaneous processing of large amounts of information is also limited. When doing simple, undemanding work people tend to get bored, but when doing complex tasks MWL is high. A high MWL is not good for health and can impair memory, communication or activity, which is why injuries can occur in some professions (pilot, soldier, doctor). In this context, understanding how the human brain functions in everyday activities and tasks is the basis of neuroergonomics (Parasuraman 2011). Tasks should be stimulating and not overloading.

While classical approaches to MWL monitoring include sets of questions i.e. NASA TLX (Hart et al. 1988) or SWAT (Reid et al. 1988), this approach is biased as it is performed

after the task/activity has been completed. At the same time, modern technology allows MWL to be monitored in real time by analyzing biophysiological signals. Among these, Electroencephalogram (EEG), Galvanic Skin Response (GSR), Heart Rate Variability (HRV), Electrocardiogram (ECG) or even temperature are descriptive when it comes to MWL. Among the above, the EEG signal seems to be one of the most interesting, as its information capacity is higher than the other bio signals (Kakkos et al 2021). The numerous scientific papers (Mahesh et al. 2021, Zammouri et al. 2018) that detect MWL from the EEG signal with high efficiency should be a direct guide for designers of exergames monitoring cognitive load.

Biophysically Motivated Gamification

Despite a number of attempts to make bio-physiological signals a control mechanism to influence task performance in digital environments, they do not allow psycho-physical parameters to be controlled to the recommended range. It is easy to find solutions that use gameplay as a cover for physical exercise (Hagen 2016), but they mostly implement this unreflectively (Martin-Niedecken 2021). Although Ketelhut et al (2022) draws attention to the conscious use of heart rate in the design of physically based games (exergames), it is difficult to find work that addresses MWL or other physiological signal modalities.

Finally, however, it should be noted that professional and automatic exercise management requires medical expertise and this cannot always be codified in a computer program. While artificial intelligence techniques support the creation of recommendation systems quite strongly, it is worth mentioning that the monitoring or visualization of key biophysiological parameters alone is as obtainable as it is possible to couple with an interactive digital simulation scenario in many rehabilitation scenarios.

REFERENCES

American College of Sports Medicine. (2000). Guidelines for exercise testing and prescription. 6th ed. Baltimore, Md: Lippincott Williams & Wilkins.

Buttussi, F. Chittaro, L., Ranon, R., & Verona, A. (2007). Adaptation of graphics and gameplay in fitness games by exploiting motion and physiological sensors. *Smart Graphics*, *07*, 85-96.

Furukado, R., & Hagiwara, G. (2021). Examining the effects of digital gameplay of the racing genre on mood and heart rate. *Journal of Digital Life*, 1.

Gómez, L.C., Hervás, R., González, I., & Villarreal, V. (2021). Studying the generalisability of cognitive load measured with eeg. *Biomedical Signal Processing and Control*, *70*, 103032.

Hagen, K., Chorianopoulos, K., Wang, A. I., Jaccheri, L., & Weie, S. (2016, May). Gameplay as exercise. In *Proceedings of the 2016 chi conference extended Abstracts on human factors in computing systems* (pp. 1872-1878).

Hart, S.G., & Staveland, L. E. (1988). Development of nasa-tlx (task load index): Results of empirical and theoretical research. In *Advances in psychology*, *52*, 139–183.

Ismail, N. A., Hashim, H. A., & Ahmad Yusof, H. (2022). Physical activity and exergames among older adults: A scoping review. *Games for Health Journal*, *11*(1), 1-17.

Kakkos, I., Dimitrakopoulos, G. N., Sun, Y., Yuan, J., Matsopoulos, G.K., Bezerianos, A., & Sun Y. (2021). Eeg finger prints of task-independent mental workload discrimination. *IEEE Journal of Biomedical and Health Informatics*, *25*(10), 3824–3833.

Ketelhut, S., Röglin, L., Kircher, E., Martin-Niedecken, A., Ketelhut, R., Hottenrott, K., & Ketelhut, K. (2022). The new way to exercise? Evaluating an innovative heart-rate-controlled exergame. *International Journal of Sports Medicine*, *43*(01), 77-82.

Ladekar, M. Y., Gupta, S. S., Joshi, Y. V., & Manthalkar R. R. (2021). Eeg based visual cognitive workload analysis using multirate iir filters. *Biomedical Signal Processing and Control*, *68*, 102819.

Martin-Niedecken, A. L. (2021). Towards balancing fun and exertion in exergames: exploring the impact of movement-based controller devices, exercise concepts, game adaptivity and player modes on player experience and training intensity in different exergame settings, *PhD Thesis*.

Masuko, S., & Hoshino, J.A. (2006). Fitness game reflecting heart rate. In *Advances in Computer Entertainment Technology*, *53*.

Niforatos, E., Tran, C., Pappas, I., Giannakos, M. (2021). Goalkeeper: A zero-sum exergame for motivating physical activity. In: *Human-Computer Interaction – INTERACT 2021*. Lecture Notes in Computer Science, vol 12934. Springer, Cham.

Parasuraman R. (2011). Neuroergonomics: Brain, cognition, and performance at work. *Current directions in psychological science*, *20*(3), 181-186.

Reid, G. B., & Nygren, T. E. (1988). The subjective workload assessment technique: A scaling procedure for measuring mental workload. In *Advances in psychology*, *52*, 185-218.

Stach, T., Graham, T. N., Yim, J., & Rhodes, R. E. (2009). Heart rate control of exercise video games. In *Proceedings of Graphics interface* 2009 (pp. 125-132).

Stewart, T.H., Villaneuva, K., Hahn, A., Ortiz-Delatorre, J., Wolf, C., Nguyen, R., Bolter, N.D., Kern, M., & Bagley J.R. (2022). Actual vs. perceived exertion during active virtual reality game exercise. *Front Rehabil Sci.*, *3*, 887740.

Zammouri, A., Moussa, A. A., & Mebrouk Y. (2018). Brain-computer interface for workload estimation: Assessment of mental efforts in learning processes. *Expert Systems with Applications*, *112*, 138–147.

Zhang, P., Wang, X., Chen, J., You, W., & Zhang W. (2019). Spectral and temporal feature learning with two-stream neural networks for mental workload assessment. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 27(6), 1149–1159.

Authors' Note

All correspondence should be addressed to
Kristiina Korjonen-Kuusipuro
South-Eastern Finland University of Applied Sciences (XAMK)
Finland
kristiina.korjonen-kuusipuro@xamk.fi
ORCID 0000-0002-8528-0237

Adam Wojciechowski
Lodz University of Technology
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 18(3), December 2022, 213–233

ATTRACTING MEMBERS OF GENERATION Z TO COMPANIES VIA SOCIAL MEDIA RECRUITING IN GERMANY

Anna Wübbelt
FOM University of Applied Sciences
Germany
ORCID 0000-0002-1020-8193

Henning Tirrel
FOM University of Applied Sciences
Germany
ORCID 0000-0002-4610-3158

Abstract: *The aim of this paper is to analyze the importance of social media in the recruitment of Generation Z, with a focus on their expectations towards social media recruiting. In a qualitative analysis, nine interviews were conducted with members of Generation Z, as well as a focus group discussion with six HR managers. Based on our research sample, both members of Generation Z and recruiters attach great importance to social media recruiting. Members of Generation Z can be characterized by their willingness to use social media, active sourcing, and the talent pool to actively support their job search. The social media platforms Instagram, Facebook, Snapchat, XING, and LinkedIn are identified as potential contact points for the generation. However, a discrepancy was uncovered between what HR managers expect in relation to the usage of social media for job searches and the actual passive use of social media for this purpose by Generation Z. In addition, a positive candidate journey and attention to various (passive) touch points are important for successful recruitment of Generation Z members. Due to the open attitude of the generation towards social media recruiting, they need to be made aware of this topic during their candidate journey.*

Keywords: *social media, recruiting, Generation Z, human resource management, candidate journey*

DOI: https://doi.org/10.14254/1795-6889.2022.18-3.2

INTRODUCTION

The trend toward publishing vacancies on social network platforms has increased in recent years (Kluemper & Rosen, 2008; Parry & Tyson, 2008). From 2018 to 2019, the percentage of companies using this medium for recruitment purposes rose from 14.3% to 17.0% (Weitzel et al. 2020b). The internet has evolved and adapted to changes and social structures, so that there has been a progression from print ads to digitally placed job ads via social media portals (Dannhäuser & Braehmer, 2017; Klaffke, 2014). This is solely possible due to the shift from web 1.0 to web 2.0 in which interaction and communication between users is possible (Bernauer, Hesse, Laick & Schmitz, 2011). Members of Generation Z (Gen Z) communicate digitally 74% of the time and only 26% in person (Schroth, 2019). A recent study also shows that social network platforms are among the most frequently used channels for job searches by students and trainees (Weitzel et al., 2020b). Recruiting and employer branding must be adapted to the communication behavior of Gen Z for getting in touch with them. In the context of the shortage of skilled workers, changes in social media use and the digital transformation, social media is an important tool for recruiting and actively sourcing new employees in the war for talent (Dannhäuser, 2017; Hesse, Mayer, Rose & Fellinger, 2019). Since members of Gen Z are a scarce but a necessary resource due to demographic change, it is essential for companies to recognize and attract them as future specialists and managers (Klaffke, 2014). At this point, it is particularly worthwhile to use social media channels, as aforementioned.

The present research will fill important theoretical and managerial gaps with regard to social media recruiting of Gen Z members. Some current studies focus on members of this generation in relation to their characteristics, values, and expectations of the world of work (Klaffke, 2014; Kring & Hurrelmann, 2019; Weitzel et al., 2020b; Hurrelmann, Köcher & Sommer, 2019), other studies shed light on the viewpoint of Gen Z (Weitzel et al., 2020a), but no existing study covers differences and similarities between the way they are searching for jobs and how Human Resource Managers (HR managers) expect them to, with a focus on social media. This emphasis was chosen as Gen Z is characterised as technoholics, i.e., they have grown up with technological change, have access to the internet at all times and depend entirely on IT (Redmond, 2013; Parker, Graf & Igielnik, 2019; Seemiller & Grace, 2017). While the term technoholics implies an addiction of technology (Güngör & Alp, 2019), members of Gen Z are also characterized as digital natives, focusing on people growing up with digital change, leading to different patterns of thinking (Prensky, 2001). This concept is also discussed critically for decades (and continues to be discussed) as the understanding of this concept has changed due to the developments of technology (Evans & Robertson, 2019). So, there is no consensus on what the term stands for (Evans & Robertson, 2019). Both concepts imply an affinity to technology which is the focus in this study.

Additionally, this is a generation defined by a high willingness to learn as well as their initiative, and both self-actualisation and a work-life cut is significant for them, meaning that border management comes into play (Krüger, 2019; Hurrelmann et al., 2019).

The aim of our research is to shine a light on this area by analyzing the role of social media in the recruitment of Gen Z members. The focus is on members of Gen Z's and HR managers' expectations regarding social media recruiting as well as on identifying similarities and differences. Therefore, the research question is: "How do members of Gen Z use social media in their job search compared to the actual use of social media in recruiting by HR managers

now and in the future?" This question will be answered as follows: First, a literature review will be conducted; second, semi-structured interviews will be implemented with members of the Gen Z; third, a focus group discussion with six HR managers will be conducted; and fourth, the results will be analyzed and synthesized. In the end, a comparison between the assumptions of HR managers and members of the Gen Z will discuss overlapping and differentiating viewpoints. Finally, theoretical and managerial implications will be presented as well as limitations of this study.

LITERATURE REVIEW

Generation Z – the future employees

The corresponding birth years of the respective generations are not consistent in the literature and assign different years to the generations (Klaffke 2014; Kring & Hurrelmann, 2019; Krüger, 2019). According to Klaffke (2014), Gen Z is composed of the cohorts born between 1996 and 2010, which are currently on the verge of the employment phase. The use of a smartphone can be seen as their most defining characteristic (Ingold, 2016) while social media are highly important for them, although they are careless and do not take data protection seriously (Hesse & Mattmüller, 2019; Krüger, 2019). In contrast, Abramova, Antonova, Campa and Popova (2022) state that young people are fearful of data security and are causing digital anxiety due to the advancement of technoscience. Regardless of age, one is exposed to social pressure and even the youngest representatives (age of 11) of Gen Z are using social media (Klaffke, 2014). For this reason, more young people are opting for a social media time-out (digital detox), by switching their smartphones off temporarily (Hurrelmann et al., 2019). Parents occupy a particularly high position in the lives of Gen Z as they serve as role models and constant companions in all matters relating to life, career or as financial advisors (Kring & Hurrelmann, 2019). Critically, however, because of this Gen Z struggles to develop independence and is sheltered by parents (Krüger, 2019). Studies have also shown that the aspect of self-actualization is becoming more significant for Gen Z (Hurrelmann et al., 2019; Weitzel et al., 2020b). Furthermore, the working atmosphere, a high level of recognition and self-actualization during work are important for them (Hurrelmann et al., 2019; Ingold, 2016; Klaffke, 2014; Neder & Scheller, 2019). In addition, a large majority of Gen Z consideres performance-based pay and a positive work-life balance important (Hurrelmann et al., 2019; Ingold, 2016; Kring and Hurrelmann, 2019; Weitzel et al., 2020a; Neder & Scheller, 2019). Rather, they even expect a work-life cut and want to strictly separate private life from work (Kring & Hurrelmann, 2019). Other gratifications such as a high income and regulated working hours as well as little overtime and low stress are essential (Hurrelmann et al., 2019). Another important factor for Gen Z is a flexible work arrangement through options offered by the company, e.g. home office, because 40% of candidates would otherwise reject a job offer (Weitzel et al., 2020a). Additionally, Gen Z expects fast and honest communication as well as timely feedback (Kring & Hurrelmann, 2019). Summing this up, the following aspects are identified as important for Gen Z: Meaningful work, performance management, work-life balance, personal connection, the big picture at work, learning, and development (Chillakuri, 2020).

Members of Generation Z related to social media recruiting

Members of Gen Z use social media between six and ten hours per day, on average (Menevse, 2019; Kajanová, Sedláček & Soósová, 2017). Facebook, Twitter, and Instagram are used most actively, but members of Gen Z have expressed concerns that HR managers might identify their profile on social media (Menevse, 2019; Karácsony & Vasa, 2020). This has even led to students actively changing their social media presence, removing tagged photos, and blocking content so that companies would have a positive impression of them (Menevse, 2019). 73.5% of companies recruit on social media using Facebook, LinkedIn, Twitter, and Instagram (Melanthiou, Pavlou & Constantinou, 2015). Referring to Muduli and Trivedi (2020), there is a significant connection between recruitment through social media and different skills both before and after hiring. In particular, credible, relevant and sufficient information is communicated via social media. For social media applications, HR managers should direct their focus on work-relevant information and avoid personal details since social media cannot predict job performance (Zhang et al., 2020). From a technical perspective, mobile recruiting means that the company website works on mobile devices such as smartphones (Strzygowski, 2014). This is of great importance since there is a significant relationship between professionalism of social media usage as well successful job placements (Winnen, Schrader & Tirrel, 2021) while social media profiles are also part of the digital identity of companies (Tirrel & Winnen, 2019).

Gen Z prefers to use search engines for job searches, followed by internet job exchanges (Weitzel et al., 2020a). Analogue media such as print media are becoming increasingly unpopular due to digitization, so that only 3% of members of Gen Z use them (Karácsony et al., 2020). According to Weitzel et al. (2020a), recommendations from acquaintances, social network platforms as well as specific programs for pupils, trainees and students are used for job searches. Gen Z wants to be contacted not only by email, but also by phone or through career networks. An active approach led to every third person becoming aware of an initially unknown company and finally applying there. Referring to Hurrelmann et al. (2019), employer review portals are not yet used by the majority of Gen Z, but websites are considered extremely helpful. Furthermore, 17% of Gen Z have used social media channels such as WhatsApp or Instagram to get information, or to rate companies. For job applications, Gen Z mainly uses company application portals and online career exchanges such as StepStone (Hurrelmann et al., 2019). Gen Z rates the possibility of applying via WhatsApp (19%), XING (18%), Facebook (17%), LinkedIn (14%), Instagram (10%) or Snapchat (4%) as low. Companies primarily use Facebook (30.4%), XING (22.8%), LinkedIn Instagram (16.4%), YouTube (5.5%), Twitter (3.7%) and professional forums (3.6%) to disseminate image advertising, so members of Gen Z already receive advertising via social media (Weitzel et al., 2020b).

About half of Gen Z prefers to be addressed directly by the companies as opposed to a traditional application, so that one third of the candidates would be willing to pay for better visibility, therefore the channel chosen for this approach is of direct importance (Weitzel et al., 2020b). However, there is rarely a consensus among candidates on the choice of channel and 50 % of candidates would like to be contacted via their private email account, which, in turn, is rejected by every fifth candidate (Weitzel et al., 2020b). When addressing potential candidates, it is important to get in touch individually and to tailor the approach to the profile by presenting a reason6 as well as obvious interest and contact details (Ullah & Witt, 2018).

Furthermore, an appealing subject and a short description of the job offer are important (Dannhäuser & Chikato, 2017). Likewise, HR managers should be aware that they are not focusing on one channel, but that various channels contribute to success and that for example by creating so-called candidate personas, they can better empathize with the target group being sought by analyzing the interests and locations of that group (Dannhäuser & Braehmer, 2017). In addition, active sourcing can also entail risks. For example, some candidates feel annoyed because too many inquiries are uninteresting and do not match their own skills or the contact inquiries only contain standardized texts and do not match their own profile (Weitzel et al., 2020b). As a consequence, candidates do not apply to the company and communicate negatively about it (Weitzel et al., 2020b). Nevertheless, some candidates respond to annoyed approaches in order to maintain contact with the companies (Weitzel et al., 2020b).

Further development is then aimed at apps that for instance represent an applicant management system (Dannhäuser, 2017). When designing the mobile application process the job advertisement must be optimized so that potential candidates always have a positive experience with the company (Böhm & Jäger, 2016; Ullah & Witt, 2018). Sending an application via a mobile device is becoming increasingly important for Gen Z (Weitzel et al., 2020a). The main reasons for this are the changed media usage of Gen Z and the technological progress of mobile devices (Böhm & Jäger, 2016). Currently, half of Gen Z still uses a device with a keyboard, but significantly less than Gen Y, so Gen Z is also increasingly relying on mobile devices for job searches (Weitzel et al., 2020a), underlying the relevance of having a website responsive in its design, i.e. website works on mobile devices (Strzygowski, 2014). One part of Gen Z even prefers to apply for a job via an app, while the other part refrains from doing so (Weitzel et al., 2020a).

Candidate experience within the candidate journey

Within a company, the candidate experience is important for reducing application dropouts, improving reputation, increasing the credibility of the employer brand and improving recruiting (Athanas & Wald, 2014). In order for a company to always take the right steps in recruiting, it is essential to deal with the candidate journey and the resulting candidate experience (Rütten, 2020). The candidate journey is initially the sum of all direct and indirect touchpoints (Verhoeven, 2020). The candidate experience refers to the overall impression that the potential candidate receives from the employer during the recruitment process (Verhoeven, 2016a). For a positive candidate experience, employers must act clearly and authoritatively in their candidate communication, be results-oriented, always treat potential candidates as equals, and show appreciation because if one of these three components is neglected, the experience suffers (Dannhäuser, 2017).

The candidate journey can also be optimized through target group-specific search engine optimization analyses, so that potential candidates receive the right information at the right time within their journey in order to have a positive experience (Ullah & Witt, 2018). Referring to Athanas and Wald (2017). In addition, a quarter of new entrants are disappointed by their new employer because the onboarding phase is poorly organized. Furthermore, for a positive candidate experience, the application process must take a maximum of six weeks (speed as a positive impact on the candidate experience, as candidates do not have to wait long for a decision (Athanas & Wald, 2014; Ryan, Ali, Hauer & Jillyan, 2017), job titles must be

formulated in an understandable way, and more than half of all applicants expect companies to have a confident online presence (Athanas & Wald, 2017). Information about potential employers becomes increasingly important the further the candidate progresses in the candidate journey (Ryan et al., 2017). If the company succeeds in this, there is a positive correlation between the candidate experience and employer branding, so that employer attractiveness increases with a more extensive use of social media channels and a talent pipeline (Allden & Harris, 2013). Likewise, a positive candidate experience cushions an applicant's disappointment at a rejection (Athanas & Wald, 2014). Verhoeven's (2016b) 6-phase model describes an ideal-typical candidate journey process.

METHODS

The methodology is a cross-sectional case study (Saunders et al., 2016). In order to be able to describe a phenomenon, which could not be grasped theoretically up to now, the case study serves as a research method to gain knowledge (Mayring, 2002; Yin, 1993). We conducted nine semi-structured interviews with members of Gen Z as well as a focus group discussion with six HR managers in November 2020 in Germany. Moreover, we conducted a focus group discussion in October 2020, again in Germany. Based on an interview guide which was prepared and pre-tested in advance, the experts were asked questions in a specific order related to the research question (Diekmann, 2005; Döring & Bortz 2016; Hussy, Schreier & Echterhoff, 2013). The empirical basis is therefore Yin's (1993) case study. In doing so, we created an interview guide with its empirical basis (cf. appendices 1 and 2). One exemplary interview question for the interviews is: "Which social media do you prefer for your job search?" and one exemplary focus group discussion question is: "How successful are you in using social media as a sourcing tool and actively targeting members of Gen Z ?" Accordingly, who is drawn into the category of expert depends on his or her special knowledge of the subject matter targeted in the question (Hitzler, 1994). To implement the two techniques presented, between-method triangulation according to Denzin's (1970) triangulation concept was used in order to be able to compare different points of view.

Within qualitative research, in contrast to quantitative research, a small sample the "conscious or purposeful selection of cases with a lot of information has developed" (purposive/ purposeful sampling) (Patton, 2002). Accordingly, the sample is purposively selected based on both theoretical and prior empirical knowledge (Döring & Bortz, 2016), cf. appendices 3 and 4 for an overview of our purposeful sample. Since our sample is not intended to represent the population of the generation, no sample error is expected. In this study, only members of Gen Z were selected as interviewees since these are members of the generation of interest (Klaffke, 2014; Oertel, 2014), again cf. appendices 3 and 4. The requirement for the focus group discussion is that participants must work in human resources departments in Germany and must already have experience in social media recruiting. According to Graefe (2020), there were approximately 238,400 people employed in the field of human resources in Germany. The participants for the interviews can be narrowed down more, as they initially belong to the Generation Z and due to research ethics, only adult interviewees were selected. Thus, the cohort contains individual born between 1996 and 2002. Based on the research question and aim of this study, it was important to us that the participants had recently been

looking for a job or training, so we interviewed the newly started trainees for this purpose. According to the German Federal Statistical Office, around 465,200 people signed a new training contract in Germany in 2020 (Statistisches Bundesamt, 2021). The interviews ended when theoretical saturation was achieved (Charmaz, 2006). All interviewees have started their apprenticeship on August 01, 2020, so that every interview partner (IP) remembered the application process well. The HR managers were also selected purposefully and recruited either via professional contacts through a proactive recruiting process using the social network XING. Two group interviewees (GI) in the focus group discussion belong to small and medium-sized enterprises (SMEs) and the other four interviewees work within a large company, according to the definition of the European Commission (2015), cf. appendix 4.

In the present study, every interview was audio-recorded, transcribed and the data was analyzed by applying the qualitative content analysis, which represents a systematic procedure (Mayring, 2015). This is reflected in the fact that the content analysis proceeds theory-guided and deductive while the steps of the analysis are derived from the theoretical considerations (Mayring, 2015). Explicit rules make it possible to follow and check the qualitative content analysis (Mayring, 2015). Within the study, the following three aggregate categories were identified: Importance of social media, use of social media, candidate experience. Figure 1 visualizes the data structure, since Corley and Gioia (2004, p. 184) state “no data structure, know nothing”.

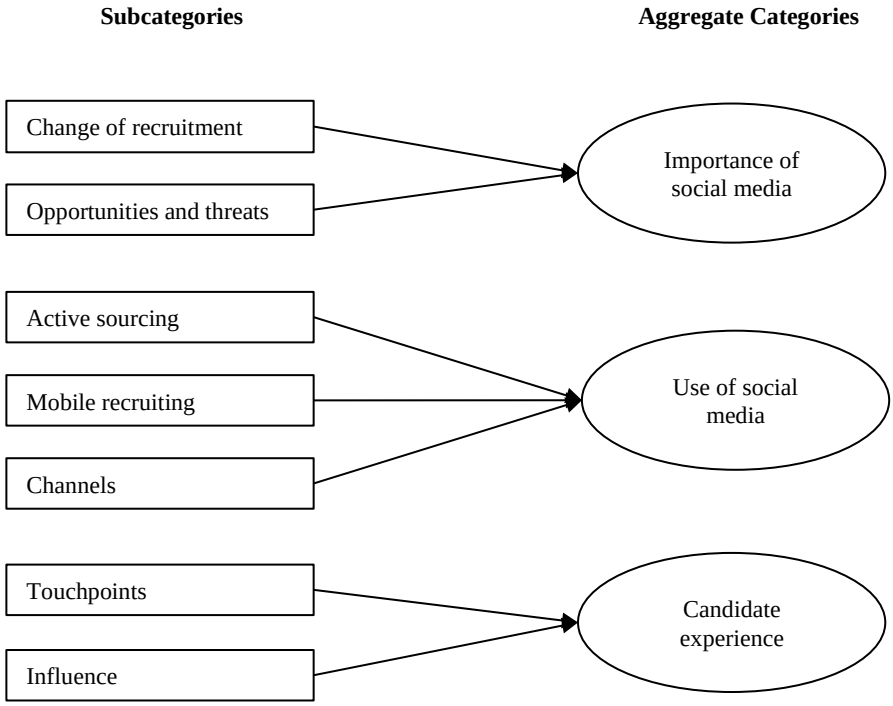

Figure 1. Data structure
[Source: Own depiction]

The data structure represents the core and the central instrument of the content analysis, which is divided into subcategories and aggregate categories, since Mayring requires a category

system (Hussy et al., 2013; Mayring, 2015). In order to be transparent an anchor example with representative data from the interviews is presented in table 1.

Table 1. Anchor examples for coding categories

1 Importance of Social Media	
A Change of recruitment	A1 “Social media has gained a lot of importance in recent years and has also shown a lot of influence on society.” (IP 6)
B Opportunities and threats	B1 “One opportunity is definitely that you are only globally networked and can communicate with people from all over the world. I would say that the risks are that a reality is portrayed that does not correspond to the actual reality and deviates from it. Many people place themselves higher than they are or spread ideals that don't correspond to reality at all.” (IP 1)
2 Use of Social Media	
C Active Sourcing	C1 “So I'll put it this way, if you're looking for a job and you really make the effort and register everywhere, then I'd be happy if someone got in touch. I'm actually quite flexible and open about that.” (IP 5)
[….]	
Full table can be obtained upon request.	

[Source: Own table]

Repeated review of the material ensured intracoder reliability. In addition, communicative validation strategies such as member checking were used (Flick, 2019). The quality criteria of Lincoln and Guba (1985), e.g., credibility and transferability as well as Mayring (2002), e.g., argumentative interpretive support and triangulation, were ensured and complied with. Now the results of the analysis are presented, following the logic of the data structure. First, the results of the interviews with members of Gen Z will be presented and second, the results will be compared with the results of the focus group discussion.

RESULTS

Importance of social media

Change of recruitment

The interviewees attach a high and constant importance to social media recruiting. Furthermore, the importance will continue to increase and rise as both younger and older people engage with social media. The reason for this high significance lies primarily in the widespread acceptance of social media within society and is associated with a right to exist. “I think it's increasing more and more, so when I see that ten-year-olds are on Instagram, the importance of social media is currently huge. We are simply growing up with it. […] So, what new functions are added, especially for companies. There are more features and I think that's why the importance will also grow more and more” (IP 2). It is already evident that the private use of social media is much higher than its use for job searches. This result on our research is due to the lack of awareness of social media recruiting, as members of Gen Z are aware that it is possible to conduct a company search via social media. In contrast, the ever-growing presence

of companies on social media is recognised by some of the members of Gen Z. Within the focus group discussion, all interviewees agree that the importance of social media increases in recruitment.

Opportunities and threats

The next subcategory shows global networking, accessibility of different generations, high awareness and versatile communication as examples of the opportunities offered. In addition, social media creates a network. Interviewee 6 even draws a comparison with analog media: "I definitely see great opportunities, because it's easier to reach people and not so complicated. In the past, people only advertised jobs in the newspaper, and at the moment that only happens every now and then I think." In addition to the opportunities mentioned by members of Gen Z, they also point out risks. First of all, time wasting is a risk, since a lot of time is spent in social media and members of Gen Z are already making a reminder to put the cell phone aside. The use of social media represents a high potential for addiction and is often characterised by fake accounts to prevent bullying, representing another risk. Due to the private use of social media, people are more often confronted with advertising from companies or products in their free time, which also represents a risk for members of Gen Z. Unless one responds to active approaches, companies often come across as intrusive.

There is also agreement on the opportunities and risks. The greatest opportunities include increased visibility, increased awareness, greater tangibility and proximity. The use of social media leads to a reduction of distance with the applicant and the company becomes globally networked: "It's about sharing your thoughts, networking with each other. Social media has become big because of its personal character. It's about networking with friends and networking across national borders. After that, companies first became aware that it can also be good for companies to private individuals. That's why something like Instagram works particularly well, because you always have the aspect of approachability and a very natural form of communication, which kind of builds bridges and breaks down walls, so that you create a closeness between companies and privates individuals" (GI 4). Furthermore, companies already achieve increased added value with the free use of the platforms. However, without an additional budget, visibility turns out to be low, which is a risk of social media recruiting from the HR managers' point of view. Due to the fast response time expected by candidates, companies need to implement quick response processes. In the future, it should be noted that the popularity of the channels is always changing and the fast pace must be taken into account when selecting channels.

Use of social media

Active sourcing

The topic of active sourcing creates new prospects for members of Gen Z as they become aware of a possibly unknown company. "Especially with companies that you don't necessarily have on your radar, you then know that they actually […] have areas that you would like to get into. I can understand that it can be very annoying when certain companies don't understand that

you say no and don't show interest, but they keep trying" (IP 1). Members of Gen Z view this potential pushiness of companies as a disadvantage. This is especially true if the companies always confront the young people with messages, even though they have communicated a lack of interest. During the active job search, however, this approach is seen as particularly attractive. Members of Gen Z are open to active sourcing and are positive about being approached via Facebook, Instagram (except from WhatsApp) and business channels.

Active sourcing is not used by HR managers when recruiting members of Gen Z. If it is used for other target groups, a combination of predefined text modules with two or three variables that fit the candidate individually is used: "No copy and paste, just change the name, but really respond to the candidate profile as well as possible so that the candidate notices that you have dealt with the profile. I believe that the more individualized the approach, the better the response rate" (GI 5). Active sourcing is mainly used for hard-to-fill positions. The search is carried out by applying Boolean search operators or a target company list with corresponding cover story.

Mobile recruiting

In addition to the use of applicant management systems, an application is typically submitted via laptop. Although user-friendliness of the websites stand out as practical and important, this is not the most relevant aspect and the resulting lack of digitization does not achieve any deterrence among members of Gen Z. "I don't think it would be a deal breaker, because I can't call an entire company into question based on the website. If I can't find out any information at all about the company on the website via mobile, then maybe" (IP 3). However, an deal breaker at this point is a career site that is difficult to find and the absence of contact persons. Mobile devices such as smartphones are used by members of Gen Z to search for information and find out about possible vacancies and potential employers at any time during the application process. The HR managers agreed on these aspects during the focus group discussion and came to comparable results.

Channels

Based on our interviews, members of Gen Z primarily use Instagram, WhatsApp, YouTube and Snapchat mainly for private purposes while Facebook is seldomly used. In addition, TikTok is shown to be more of an entertainment site which is not very well regarded and is viewed as inappropriate for job searches. Interview 3 states: "TikTok is something for watching funny videos and having fun with in your free time, but not for a serious job search". With regard to the search for a new employer, social media are currently hardly taken into consideration and the application takes place almost exclusively for the via the website. Here, the career site stands out as the first source of information about the companies and is the focus of the application process. "I have used social media rather less in my job search. I mainly went through their website and didn't pay attention to how they represented themselves on social media" (IP 1). This is related to ignorance of vacancies and social media presences since the members of Gen Z are not informed: "I didn't use social media because I didn't know" (IP 8). When social media was used for job searches, members of Gen Z felt that people already knew the colleagues and could gain internal insights from the company in this way: "They also

showed a lot of what the employees did in the company. I have to say that I liked that and I had the feeling that I knew the people much better" (IP 2). Furthermore, the application Snapchat is not used for job searches either, though members of Gen Z would subscribe to a trainee-managed Snapchat account and check the content regularly. With regard to business channels, XING and LinkedIn are not very well known to members of Gen Z, although their features can be helpful: "That sounds really good and I think it would be perfect for me. I will definitely take a closer look at that and can well imagine that I will use it more often" (IP 9).

When using social media channels, HR managers believe it is important that they are well-maintained and authentic. All group interviewees agree that a company must focus on one medium at the beginning of the social media journey in order to be successful and that the distribution of tasks within the team must be clearly structured. For group interviewee 4, daily communication takes place on the channels. Here, the strategy of lead generation is pursued with a target group-specific approach and a job spreader, so that the goal is to attract as many potential candidates as possible from the job market. To effectively create the strategy, the target group definition as well as the employer brand definition per channel, an editorial plan can be used. HR managers use the business networks XING and LinkedIn as well as Facebook, YouTube and Instagram for recruitment. Moreover, Snapchat and TikTok are predominantly used for recruiting members of Gen Z, with the Snapchat account being managed by current trainees. "We want to communicate and present ourselves in such a way that it remains authentic, and that's why it's clearly anchored in our strategy that we also get our employees on board. […] Every picture or every video includes our employees or our trainees" (GI 4).

Candidate experience

Touchpoints

During the candidate journey, members of Gen Z want to be contacted two to three times a week to build a candidate experience. Every contact with members of Gen Z indicates that the company is interested in the candidate. Interviewee 3 states: "Well, I think that if you are contacted often, it shows that they are interested. It's not supposed to be spam when I get called three times a day, but I think if you get in touch regularly, that already shows interest, so it's good". Internal events, trade fairs or cooperation between schools and employers are used for direct contacts. Job alerts via email as well as talent pools are relatively unknown to members of Gen Z, although a constant contact is understood as positive. According to members of Gen Z, the contact should be by email. "Actually, only via my email address. I regularly check it, and if I've given my mobile phone number somewhere, it's also fine if they call me" (IP 7).

To ensure a successful candidate experience, all six interviewees in the focus group discussion stated that all phases of the process are important. It is essential that all phases are given the same relevance and are coordinated with each other: "It's like a cycle. If I bring people on board and I don't perform afterwards, they just jump off again. Then you have costs again for the new recruitment and you have to convince new people. I then find the people who dropped out again on Kununu. It's all interdependent, and for me there is no phase that is more or not so important" (GI 3). Measuring the candidate experience is very difficult, but key

performance indicators can be defined and analyzed, e.g. conversion rate, interaction rate, or active applicant count in order to identify good or bad aspects of the candidate experience.

Influence

Although members of Gen Z can be influenced by social media, according to our research, the idea of posting negative comments on it is not common among them as they prefer to resolve their issues directly with the employer. Furthermore, a high level of influence is exerted by family and acquaintances as well as by influencer marketing. The employer rating platform Kununu is not very well known, although members of Gen Z would be influenced by these ratings if they were used: "The apprentices didn't give much information, of course, but that's when I looked at it, and because of the bad evaluations, some companies were kicked out. I simply didn't want to take the risk that they wouldn't support the apprentices, for example. You are quickly influenced by what you read, and then it doesn't matter if a fake account wrote it. You also don't think about the sources and whether it's really true or not. I do think that's a certain risk for companies, but it's difficult to change or prevent anything" (IP 6). Nevertheless, members of Gen Z form its own opinions and this is always most important to them.

According to the group interviewees, members of Gen Z are quicker to post something negative than positive on social media and will abandon the application process due to negative reviews. Members of Gen Z are classified by HR managers as being influenced by social media as well as friends and acquaintances. In addition to employer review portals, influencer marketing also plays a significant role. For this reason, it is important for the HR managers to respond to and refute negative comments: "The good thing is that you can craft the whole thing. […] I was able to refute every negative assessment later on, and the company, without treating the applicant negatively, came out in a positive light, in my opinion. You get a good balance by writing 'Yes, I understand that and also that you didn't like this and that. We see it a little differently'. It's always the same pattern and you can pick up a lot of things that are subjective" (GI 6).

CONCLUSIONS

Both, the nine interviews and the focus group discussion with six HR Managers, uncovered that the importance of social media recruiting is steadily increasing and that it is no longer possible to recruit without using social media. Some positive and negative effects outlined in the literature were confirmed by the qualitative analysis. For example the constant accessibility and usability represent a great opportunity, whereas the costs and resources represent a risk (Bärmann 2012; Gabriel & Röhrs, 2017). This study highlights that members of Gen Z are largely unaware that social media can be used for job searches, being in contrast with existing literature (cf. Abramova et al., 2022). Consequently, companies need to make their target group aware of social media throughout the candidate journey and raise their awareness, e.g. by being able to provide further internal insights on social media channels during the recruiting process. Therefore, candidates can better identify themselves with companies and their employees.

Due to members of Gen Z's preference for applying via the company's career website, it is important to set it up well and in a structured manner. Since the career website serves as the

first source of information, it is also advisable for companies to ensure that it can be found quickly. Research has shown that the career website is the heart of recruiting (Ullah & Witt, 2018). Furthermore, it is significant that the career website is presented in a user-friendly manner on mobile devices, so that it is not a deterrent for members of Gen Z. The results of the qualitative analysis uncover a discrepancy compared to the studies described. These show that members of Gen Z tend to use a mobile device although in the interviews conducted, only interviewee 9 applies via smartphone. At this point, companies should link their social media channels directly to the career website because this study highlights that members of Gen Z are often unaware of them. The social media content should concentrate on internal insights and not just focus on the company's products, as this content does not coincide with the expectations of members of Gen Z.

In terms of the various platforms, Instagram, WhatsApp, YouTube and, in some cases, Snapchat are used for private purposes, whereas social media are rarely considered for job searches. TikTok is characterized by members of Gen Z more as an entertainment site and they probably do not use this medium for their job search. However, even on private networks, it is possible to reach out to members of Gen Z by posting ads. Furthermore, pages within the platforms specifically geared to members of Gen Z arouse interest and, if the accounts are run by current trainees, this interest intensifies. This result is also evident in research, underlining its importance (Schröter-Unlü, 2017; Ullah & Witt, 2018). The focus group discussion reveals that companies use Facebook, YouTube, and Instagram for recruitment in addition to the business networks XING and LinkedIn. At this point, companies are recommended to focus on the platforms Instagram, Snapchat as well as XING and LinkedIn to address members of Gen Z in a target group-oriented manner. In doing so, it is important that content is tailored to them and authentic, e.g. by letting apprentices share their views on the employer in addition to application tips (Ullah & Witt, 2018). Based on the focus group discussion, it is also possible to recommend that companies include their own employees as ambassadors within the use of social media, thereby ensuring a certain authenticity. In addition, an editorial plan lends itself to effective use and a predefined strategy for social media activities is essential for success (Bärmann, 2012; Ullah and Witt, 2018; Weitzel et al., 2020b).

Furthermore, our research shows that members of Gen Z's use of business channels ensures the openness to active sourcing identified in the interviews. The focus group discussion shows that HR managers are not currently using active sourcing to reach the members of Gen Z. In addition to the business channels, companies may also actively approach members of Gen Z via Facebook and Instagram, although they should not act in an intrusive manner. It is important that companies write to potential candidates individually and under consideration of their profile. In addition to internal events, trade fairs and cooperation between schools and employers also attract a lot of attention with the initially unknown possibilities of a talent pool and job alerts, as potential contact points during the candidate journey. Therefore, companies should establish a talent pool and have a job alert set up. In addition, companies should draw attention to these opportunities within social media and HR managers should also communicate these tools to the applicants at all stages along the candidate journey. To build a positive candidate experience, companies need to contact members of Gen Z two to three times a week. In addition, despite their own opinions always being the most important, the influence of family and acquaintances as well as social media plays an essential role in the candidate experience. At this point, it is advisable for companies to engage with the employer review platform

Kununu, as members of Gen Z referred to its influence in the interviews despite their tendency not to use it at present. Influencing families and acquaintances can be ensured, for example, through a positive employer brand, active employee referral marketing, and participation in trade fairs and cooperation with schools. The six HR Managers of the focus group discussion revealed that measuring the candidate experience involves a great deal of difficulty. However, HR managers use previously created indicators for measuring the success. This result is also reflected in research (Brickwedde, 2017; Gabriel & Röhrs, 2017; Ullah & Witt, 2018). In addition, it is advisable to respond to negative reviews within the Kununu platform in order to invalidate them and put the company back in a positive light. In practice, the candidate experience is also a cycle in which all phases must be coordinated with each other and one phase actively influences the other phase. For this reason, companies must actively take into account the six phases according to Verhoeven (2016b) shown within the theoretical principles when recruiting members of Gen Z. This can be implemented within the recruitment process, especially in the attraction as well as the information phase through social media, where potential candidates become aware of the company. With regard to the use of social media, the results are partly complementary and partly contradictory. On the one hand, this is due to the fact that the companies use YouTube, Instagram and to some extent Snapchat and TikTok for recruiting members of Gen Z, which reflects the generation's preferences. However, there is a discrepancy in the use of TikTok, because members of Gen Z use this medium exclusively privately and cannot imagine using it in their job search. Furthermore, Gen Z would like to be actively approached, whereas HR managers do not engage in active sourcing with them.

Summing this up, our study uncovered that members of Gen Z use social media mainly for private purposes and are rarely aware of its opportunities in seeking jobs or informing themselves about potential employers. Moreover, members of Gen Z do not use social media and technology in general to their full potential (do not prefer applying by using mobile devices). The HR managers did not expect members of Gen Z to be so uninformed about these possibilities, as members of Gen Z seem to have high affinity towards technology.

Therefore, there is a discrepancy about what members of Gen Z really know about social media recruiting as well as what they make use of and what the HR managers expect them to know/use. As a consequence, both have to gain more knowledge about what is really happening and what is desired. Therefore, HR managers should focus on informing members of Gen Z about the possibilities of social media recruiting instead of expecting them to mainly apply from a mobile device by using social media accounts. This study shines light on both perspectives and clarifies the expectations of both parties.

The diverse results of the study would have achieved a higher comparability among themselves if the sample had been homogeneously selected. Despite the evaluation by qualitative content analysis according to Mayring (2015, 2002) and the adherence to quality criteria, a certain degree of subjectivity is present. In addition, this qualitative study was conducted under the research philosophy of interpretivism. This implies that the focus is on interpreting the results obtained and gaining a deeper understanding of the phenomenon under study within this sample, rather than striving for representative results for the entire generation.

Furthermore, the study was solely conducted in Germany and does not allow any conclusions to be drawn for other countries or cultures. The topic of social media recruiting and the law also was not discussed, although the legal framework for the search for qualified employees via social media should not be disregarded (cf. Ulbricht, 2017). In addition, the

issue of data protection with the General Data Protection Regulation has also not been taken into account, whereby this is important for the selection of channels (cf. Walzer et al., 2019). For further research, it is therefore essential to include both, legal framework conditions and compliance with data protection, in the context of social media recruiting.

For further research, it is essential to consider the expectations of members of Gen Z as well as the candidate experience created within the candidate journey. Due to the constantly advancing digitalization, it can be assumed that the user behavior of members of Gen Z (and the subsequent Gen Alpha) will also continuously develop with regard to social media. Future HR research should analyze how social media recruiting and the candidate experience develop over time (e.g. after implementation of the aforementioned recommendations) and research again how both, members of Gen Z as well as HR managers, opinions develop. Moreover, a quantitative study could be conducted in order to fully understand which social media are used (or expected to be used) to derive representative knowledge gaps of members of Gen Z and HR managers, as initially presented in this study.

REFERENCES

Abramova, S. B., Antonova, N. L., Campa, R., & Popova., N. G. (2022). Digital Fears Experiencey by Young People in the Age of Technoscience. *Changing Societies & Personalities*, 6(1), 56–78. https://doi.org/10.15826/csp.2022.6.1.163

Allden, N., & Harris, L. (2013). Building a positive candidate experience towards a networked model of e-recruitment. *Journal of Business Strategy*, *34*(5), 36–47. https://doi.org/10.1108/JBS-11-2012-0072

Athanas, C., & Wald, P. M. (2014). *Candidate Experience Studie.* Berlin: meta HR Unternehmensberatung GmbH & stellenanzeigen.de.

Athanas, C., & Wald, P. M. (2017). *Candidate Experience Studie.* Berlin: meta HR Unternehmensberatung GmbH & stellenanzeigen.de.

Bärmann, F. (2012). *Social Media im Personalmanagement. Facebook, Xing, Blogs, Mobile Recruiting und Co. erfolgreich einsetzen.* Heidelberg: mitp - Verlagsgruppe Hüthig Jehle Rehm GmbH.

Bernauer, D., Hesse, G., Laick, S., & Schmitz, B. (2011). *Social Media im Personalmarketing. Erfolgreich in Netzwerken kommunizieren.* Köln: Wolters Kluwer Deutschland GmbH.

Böhm, S., & Jäger, W. (2016). Mobile Candidate Experience - Anforderungen an eine effiziente Bewerberansprache über mobile Karriere-Websites. *HMD Praxis der Wirtschaftsinformatik, 53*(6), 785–801. https://doi.org/10.1365/s40702-016-0270-5

Brickwedde, W. (2017). Social Media Recruiting für Fortgeschrittene. In R. Dannhäuser (Ed.), *Praxishandbuch Social Media Recruiting. Experten Know-how / Praxistipps / Rechtshinweise* (457–468). Wiesbaden: Springer Fachmedien.

Charmaz, K. (2006). *Constructing grounded theory. A practical guide through qualitative analysis.* London: Sage Publications.

Chillakuri, B. (2020). Understanding Generation Z expectations for effective onboarding. *Journal of Organizational Change Management*, *33*(7), 1277–1296. https://doi.org/10.1108/JOCM-02-2020-0058

Corley, K. G., & Gioia, D. A. (2004*).* Identity ambiguity and change in the wake of a corporate spin-off. *Administrative Science Quarterly*, *49*(2), 173–208. https://doi.org/10.2307/4131471

Dannhäuser, R. (2017). Trends im Recruiting. In R. Dannhäuser (Ed.), *Praxishandbuch Social Media Recruiting. Experten Know-How/Praxistipps/Rechtshinweise* (1-40). Wiesbaden: Springer Fachmedien.

Dannhäuser, R., & Braehmer, B. (2017). Active Sourcing in der Praxis. In R. Dannhäuser (Ed.), *Praxishandbuch Social Media Recruiting. Experten Know-how/Praxistipps/Rechtshinweise* (407-434). Wiesbaden: Springer Fachmedien.

Dannhäuser, R., & Chikato, D. (2017). Zünden Sie mit XING Ihren Recruiting-Turbo! In R. Dannhäuser (Ed.), *Praxishandbuch Social Media Recruiting. Experten Know-how/Praxistipps/Rechtshinweise* (41-142). Wiesbaden: Springer Fachmedien.

Denzin, N. K. (1970). *The Research Act - A Theoretical Introduction to Sociological Methods.* Chicago: Aldine.

Diekmann, A. (2005). *Empirische Sozialforschung. Grundlange, Methoden, Anwendungen.* Reinbeck: Rowohlt.

Döring, N., & Bortz, J. (2016). *Forschungsmethoden und Evaluation in den Sozial- und Humanwissenschaften*. Berlin Heidelberg: Springer-Verlag.

European Commission (2015). *Benutzerleitfaden zur Definition von KMU*, Luxemburg: Amt für Veröffentlichungen der Europäischen Union.

Evans, C., & Robertson, W. (2019). The four phases of the digital natives debate. *Human Behavior and Emerging Technologies, 2*(3), 269-277. https://doi.org/10.1002/hbe2.196

Flick, U. (2019). Gütekriterien qualitativer Sozialforschung. In N. Baur, & J. Blasius (Eds.), *Handbuch Methoden der empirischen Sozialforschung* (473-488). Wiesbaden: Springer Fachmedien.

Gabriel, R., & Röhrs, H. (2017). *Social Media. Potenziale, Trends, Chancen und Risiken*. Wiesbaden: Springer Gabler.

Graefe, L (2022). *Anzahl der Beschäftigten im Bereich Personalwesen in Deutschland*. Retrieved from https://de.statista.com [22.02.2022].

Güngör, A., & Alp, G. T. (2019). Generational motivation differences at the R&D centers: Gen Y and Gen Z. *International Scientific Journal "Innovations", V*(2), 50-53.

Hesse, G., Mayer, K., Rose, N., & Fellinger, C. (2019). Herausforderungen für das Employer Branding und deren Kompetenzen. In G. Hesse, & R. Mattmüller (Eds.), *Perspektivwechsel im Employer Branding. Neue Ansätze für die Generationen Y und Z* (55–104). Wiesbaden: Springer Fachmedien.

Hitzler, R. (1994). Wissen und Wesen des Experten. Ein Annhäerungsversuch - zur Einleitung. In R. Hitzler, A. Honer, & C. Maeder (Eds.), *Expertenwissen. Die institutionalisierte Kompetenz zur Konstruktion von Wirklichkeit* (13–30). Wiesbaden: Springer Fachmedien.

Hurrelmann, K., Köcher, R., & Sommer, M. (2019). *Kinder der Einheit. Die McDonald's Ausbildungsstudie 2019.* Düsseldorf: McDonald's Deutschland LCC.

Hussy, W., Schreier, M., & Echterhoff, G. (2013). *Forschungsmethoden in Psychologie und Sozialwissenschaften für Bachelor.* Berlin Heidelberg: Springer-Verlag.

Ingold, J. (2016). *Generation Z - eine Metastudie über die kommende Generation.* Biglen: Triple-a-Team AG.

Kajanová, H., Sedláček, M., & Soósová, V. (2017). Attitudes of young people to job searching through social media. Case of Slovakia. *Economics and Sociology, 10*(1), 152–168. Doi: 10.14254/2071-789X.2017/10-1/11

Karácsony, P., & Vasa, L. (2020). Attitudes of Z generations to job searching through social media. *Economics and Sociology, 13*(4), 227–240. Doi:10.14254/2071-789X.2020/13-4/14

Klaffke, M. (2014). Erfolgsfaktor Generationen-Management - Handlungsansätze für das Personalmanagemen. In M. Klaffke (Ed.), *Generationen-Management. Konzepte, Instrumente, Good-Practice-Ansätze* (3–26). Wiesbaden: Springer Fachmedien.

Kluemper, D. H., & Rosen, P. A. (2009). Future employment selection methods: Evaluating social networking web sites. *Journal of Managerial Psychology, 24*(6), 567-580. https://doi.org/10.1108/02683940910974134

Koch, T., Gerber, C., & de Klerk, J. J. (2018), The impact of social media on recruitment: Are you LinkedIn? *SA Journal of Human Resource Management, 16*, 1-14. https://doi.org/10.4102/sajhrm.v16i0.861

Kring, W., & Hurrelmann, K. (2019). *Die Generation Z erfolgreich gewinnen, führen, binden.* Herne: NWB Verlag GmbH & Co. KG.

Krüger, K. (2019). Gesellschaftlicher Wertewandel. Generation X, Y, Z - und dann? In H. Klaus, & H. J. Schneider (Eds.), *Personalperspektiven. Human Resource Management und Führung im ständigen Wandel* (39–72). Wiesbaden: Springer Fachmedien.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic Inquiry.* Newbury Park: Sage.

Mayring, P. (2002). *Einführung in die qualitative Sozialforschung - eine Anleitung zu qualitativem Denken.* Weinheim: Beltz.

Mayring, P. (2015). *Qualitative Inhaltsanalyse. Grundlagen und Techniken.* Weinheim und Basel: Beltz.

Melanthiou, Y., Pavlou, F., & Constantinou, E. (2015). The use of social network sites as an e-recruitment tool. *Journal of Transnational Management, 20*(1), 31–49. https://doi.org/10.1080/15475778.2015.998141

Menevse, A. (2019). Impact of job seraches on self-control at social media. *Educational Research and Reviews,* 14(9), 320–326. https://doi.org/10.5897/ERR2019.3700

Muduli, A., & Trivedi, J. J. (2020). Recruitment methods, recruitment outcomes and information credibility and sufficiency. *Benchmarking: An International Journal, 27*(4), 1615-1631. https://doi.org/10.1108/BIJ-07-2019-0312

Neder, P., & Scheller, S. (2019). *Digital Candidate Journey.* Bayreuth: Universität Bayreuth.

Oertel, J. (2014). Baby Boomer und Generation X - Charakteristika der ertablierten Arbeitnehmer-Generationen. In M. Klaffke (Ed.), *Generationen-Management. Konzepte, Instrumente, Good-Practice-Ansätze* (27-56). Wiesbaden: Springer Fachmedien.

Parker, K., Graf, N., & Igielnik, R. (2019). *Generation Z looks a lot like millennials on key social and political issues.* Retrieved from https://www.pewresearch.org/social-trends/2019/01/17/generation-z-looks-a-lot-like-millennials-on-key-social-and-political-issues/ [30.10.2021].

Parry, E., & Tyson, S. (2008). An analysis of the use and success of online recruitment methods in the UK. *Journal of Human Resource Management, 18*(3), 257–274. https://doi.org/10.1111/j.1748-8583.2008.00070.x

Patton, M. Q. (2002). *Qualitative research and evaluation methods*. Thousand Oaks, California: Sage.

Prensky, M. (2001). Digital natives, digital immigrants part 1. *On the Horizon, 9*(5), 1-6. https://doi.org/10.1108/10748120110424816

Redmond, P. (2013). Talking about my generation: Exploring the benefits engagement *challenge*. London: Barclays Bank PLC.

Rütten, M. (2020). Nur etwas für Konzerne oder klappt Recruiting Analytics auch im Mittelstand? In T. Verhoeven (Ed.), *Digitalisierung im Recruiting. Wie sich Recruiting durch künstliche Intelligenz, Algorithmen und Bots verändert* (161–182). Wiesbaden: Springer Fachmedien.

Ryan, A. M., Ali, A. A., Hauer, T., & F., Jillyan (2017). Timeliness is key to the candidate experience. *Personnel Assessment and Decisions, 3*(1), 38–50. https://doi.org/10.25035/pad.2017.004

Saunders, M., Lewis, P., & Thornhill, A. (2016). *Research Methods for Business Students.* Harlow: Pearson Education Limited.

Schroth, H. (2019). Are you ready for Gen Z in the workplace? *California Management Review, 6*(13), 5–18. https://doi.org/10.1177%2F0008125619841006

Schröter-Unlü, M. (2017). Karriere-Blogs. In R. Dannhäuser (Ed.), *Praxishandbuch Social Media Recruiting. Experten Know-how/Praxistipps/Rechtshinweise* (245-276). Wiesbaden: Springer Fachmedien.

Seemiller, C., & Grace, M. (2017). Generation Z: Educating and engaging the next generation of students. *In Practice, 22*(3), 21-26. https://doi.org/10.1002/abc.21293

Statistisches Bundesamt (2021). *Zahl der neuen Ausbildungsverträge im Jahr 2020 um 9,4 % gesunken. Corona-Krise hat deutlichen Einfluss auf den Ausbildungsmarkt.* Retrieved from https://www.destatis.de/DE/Presse/Pressemitteilungen/2021/04/PD21_187_212.html [15.10.2021].

Stock-Homburg, R., & Groß, M. (2019). *Personalmanagement. Theorie – Konzepte – Instrumente.* Wiesbaden: Springer Verlag.

Strzygowski, S. (2014). *Personalauswahl im Vertrieb. Wie Sie die passenden Top-Performer finden und gewinnen.* Wiesbaden: Springer-Fachmedien.

Tirrel, H., & Winnen, L. (2019). Die digitale Identität der DAX-30-Unternehmen aus Sicht des Personalmarketings 2.0. Modernes Recruiting: Eine Status-quo Analyse. In L. Winnen, A. Rühle, & A. Wrobel (Eds.), *Innovativer Einsatz digitaler Medien im Marketing. Analysen, Strategien, Erfolgsfaktoren, Fallbeispiele* (29-46), Wiesbaden: Springer Gabler. https://doi.org/10.1007/978-3-658-16774-5_3

Ulbricht, C. (2017). Social Media Recruiting & Recht - Rechtliche Rahmenbedingungen bei der Recherche und Gewinnung von Mitarbeitern über XING, Facebook & CO. In R. Dannhäuser (Ed.), *Praxishandbuch Social Media Recruiting. Experten Know-how/Praxistipps/ Rechtshinweise* (333-356). Wiesbaden: Springer Fachmedien.

Ullah, R., & Witt, M. (2018). *Praxishandbuch Recruiting. Grundlagenwissen - Prozess-Know-how- Social Recruiting*. Stuttgart: Schäffer-Poeschel Verlag.

Verhoeven, T.(2016a). Zahlen, Daten, Fakten zu Candidate Experience in Deutschland. In T. Verhoeven (Ed.), *Candidate Experience. Ansätze für eine positiv erlebte Arbeitgebermarke im Bewerbungsprozess und darüber hinaus* (25–32). Wiesbaden: Springer Fachmedien.

Verhoeven, T. (2016b). Die Candidate Journey und Touchpoints. In T. Verhoeven (Ed.), *Candidate Experience. Ansätze für eine positiv erlebte Arbeitgebermarke im Bewerbungsprozess und darüber hinaus* (33-44). Wiesbaden: Springer Fachmedien.

Verhoeven, T. (2020). Digital Candidate Experienc. In T. Verhoeven (Ed.), *Digitalisierung im Recruiting. Wie sich Recruiting durch künstliche Intelligenz, Algorithmen und Bots verändert* (51-66). Wiesbaden: Springer Fachmedien.

Walzer, D., Hagen, I., Roth, D., Scibetta, L., Funk, C., Müller, P., Ullah, R., & Dannhäuser, R. (2019): Wie wird ein Unternehmen agil, attraktiv und aufmerksamkeitserregend - und bleibt es auch dauerhaft? In D. Walzer (Ed.), *Young Professionals gewinnen, halten, weiterentwickeln. Zukunftsfähige Mitarbeiterbindung von Nachwuchskräften* (1-82). Wiesbaden: Springer Fachmedien.

Weitzel, T., Maier, C., Weinter, C., Pflügner, K., Oelhorn, C., Wirth, J., & Laumer, S. (2020a). *Generation Z - die Arbeitnehmer von morgen.* Bamberg: Otto-Friedrich-Universität Bamberg.

Weitzel, T., Maier, C., Weinter, C., Pflügner, K., Oelhorn, C., Wirth, J., & Laumer, S (2020b). *Social Recruiting und Active Sourcing.* Bamberg: Otto-Friedrich-Universität Bamberg.

Winnen, L., Schrader, S., & Tirrel, H. (2021). Der Einfluss von Social Media (im Employer Branding) auf den Stellenbesetzungserfolg: Eine quantitative Analyse. In Tirrel, H., Winnen, L., & Lanwehr, R. (Eds.), *Digitales Human Resource Management. Aktuelle Forschungserkenntnisse, Trends und Anwendungsbeispiele* (173-194). Wiesbaden: Spriger Gabler. https://doi.org/10.1007/978-3-658-35590-6_11

Yin, R. K. (1993). *Applications of Case Study Research*. Newbury Park: SAGE.

Zhang, L., Arnold, J. D., Lievens, F., van Iddekinge, C. H., Roth, P. L., Lanivich, S. E., & Jordan, S. L. (2020). What's on job seekers' social media sites? A content analysis and effects of structure on recruiter judgments and predictive validity. *Journal of Applied Psychology, 105*(12), 1–17. https://doi.org/10.1037/apl0000490

Authors' Note

All correspondence should be addressed to
Henning Tirrel
FOM University of Applied Sciences
Münster, Germany
henning.tirrel2@fom-net.de

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

APPENDIX

Appendix 1. Assignment of the interview questions with the empirical basis – interviews

Interview questions	Empirical basis
How do you think about the current importance of social media in recruiting?	cf. Hurrelmann et al., 2019; Klaffke, 2014
How do you currently perceive social media recruiting?	cf. Hurrelmann et al., 2019; Menevse, 2019; Weitzel et al., 2020a
What opportunities and risks do you experience in social media recruiting?	cf. Bärmann, 2012; Gabriel and Röhrs, 2017; Krämer et al., 2014
Which social media networks do you prefer for your job search?	cf. Hurrelmann et al., 2019; Kajanová et al., 2017
How often do you apply via mobile devices?	cf. Weitzel et al., 2020a
How important is the user-friendliness of the career sites and social media networks when you open them on your smartphone?	cf. Weitzel et al., 2020a
How do you think about being actively contacted by recruiters via social media networks and which channels do you prefer here?	cf. Weitzel et al., 2020b
What expectations do you have during the application process?	cf. Hurrelmann et al., 2019
How often and where (in online social media) may a potential employer contact you?	cf. Ullah and Witt, 2018
What leads you to post a negative review about a company on social media?	cf. Athanas and Wald, 2014; Ryan et al., 2017
To what extent do personal positive or negative experiences with the company have an impact on your perception?	cf. Allden and Harris, 2013; Athanas and Wald, 2014; Hurrelmann et al., 2019

Appendix 2. Assignment of the interview questions with the empirical basis – Focus group discussion

Interview questions	Empirical basis
How do you think about the current importance of social media in recruiting?	cf. Hurrelmann et al., 2019; Klaffke, 2014
If possible, reconsider a time without social media. What sourcing tools did you use? How effective were they?	cf. Koch, Gerber and de Klerk, 2018
What opportunities and risks do you experience in(not) using social media?	cf. Bärmann, 2012; Gabriel and Röhrs, 2017; Stock-Homburg/ Groß, 2019
(How) Has your recruiting improved after implementing social media?	cf. Bärmann, 2012; Gabriel and Röhrs, 2017; Stock-Homburg/ Groß, 2019
For which purposes do you use social media?	cf. Koch et al., 2018
What does your HR marketing mix look like in terms of social media?	cf. Weitzel et al., 2020b
How often and why do you use the different social media channels?	cf. Koch et al., 2018
How successful are you in using social media as a sourcing tool by focusing on the Generation Z?	cf. Koch et al., 2018
When you actively source potential candidates, what do you look for in profiles?	cf. Dannhäuser and Braehmer, 2017; Ullah and Witt, 2018
How can companies use standardized tools efficiently and still achieve a high degree of individualization in the form of a perceived personal and appreciative approach to candidates?	cf. Dannhäuser, 2017
How do you structure your social media activities?	cf. Bärmann, 2012; Ullah and Wittm 2018; Weitzel et al., 2020b
Which aspects are important to Generation Z during the application process and at work?	cf. Hurrelmann et al., 2019; Weitzel et al., 2020a
Which channels does Generation Z use and prefer to apply for a job from your point of view?	cf. Hurrelmann et al., 2019; Kajanová et al., 2017
How do you realize a positive candidate experience? What do your success factors look like?	cf. Dannhäuser, 2016c; Ullah and Witt, 201; Verhoeven 2016d
How influenced is Generation Z by positive or negative experiences from family and friends in the application process?	cf. Allden and Harris, 2013; Athanas and Wald, 2014; Hurrelmann et al. 2019

Appendix 3. Sample – interviews

Interview partner (IP)	Year of birth	Work experience	Current education
1	2001	Voluntary internships	Industrial clerk
2	2002	Part-time jobs	Industrial clerk
3	2001	Voluntary internships	Industrial clerk
4	2001	Student internships	Industrial clerk
5	2002	Training as a warehouse logistics specialist	Machinist
6	2001	Part-time jobs, student internships	Industrial clerk
7	2001	Voluntary internships	Electronics technician for industrial engineering
8	1997	Apprenticeship as electrician, work and travel, voluntary work experiences	Educator
9	2002	Student internships	Carpenter

Appendix 4. Sample overview – focus group discussion

Group participant	Industy	Current professional activity
1	Mechanical engineering	Twenty years as a training coordinator, vocational educator and purchaser in a medium-sized company
2	Automotive Industry	HR manager in recruiting in a large company
3	Public administration	HR consultant and member companies in a large company
4	Public administration	HR marketing manager with focus on social media within trainee recruitment in a large company
5	Service / Banking, finance, insurance	Recruiting manager in a medium-sized company
6	Logistics	Social media expert for recruiting in a large company

Human TECHNOLOGY

ISSN: 1795-6889

https://ht.csr-pub.eu Volume 18(3), December 2022, 234–249

TECHNOSTRESS OF STUDENTS DURING COVID-19 - A SIGN OF THE TIME?

Konrad Kulikowski
University of Social Sciences
Poland

Łukasz Sułkowski
Jagiellonian University
Department of Higher Education Institutions
Poland

Sylwia Przytuła
Wroclaw University of Science and Technology
Department of Organization and Management
Poland

Martina Rašticová
Mendel University in Brno
Department of Law and Social Sciences
Czech Republic

Abstract: *University students are considered digital natives but they often have difficulties in the effective integration of information technology (IT) into their study routine. To unravel this puzzle we proposed a model of IT effects on students' well-being, based on the Job Demands-Resources theory, one of the most widely used models of human well-being in organizational contexts. We described three processes affecting students' well-being. A techno-stress process generates strain via an increase in study demands. A techno-enrichment process sparks motivation through the creation of energizing study techno-resources. A dual-nature techno-challenge process sparks motivation but also creates strain. Our elaboration might help to reconcile conflicting findings on the role of IT in remote learning and contribute to a better understanding of the effect of IT on students. The proposed theoretical model might also spark further empirical research and provide guidelines for research on IT use in university learning.*

Keywords: *technostress, IT resources, IT demands, motivation, techno-challenges.*

DOI: https://doi.org/10.14254/1795-6889.2022.18-3.3

INTRODUCTION

The implementation of technology in the learning processes in academia started some years ago (Rayan et al., 2017), and it has generated various educational benefits both for teachers and students. On the whole, the percentage of users significantly increased during the COVID-19 pandemic (Alvarez-Risco et al., 2021; Sun et al., 2020). Universities were suddenly forced into remote teaching and learning, which led to many disadvantages for teachers (Kulikowski, Przytuła, Sułkowski, 2021a) and students' job outcomes (Kulikowski, Przytuła, Sułkowski, 2021b).

In general, e-learning is considered less productive than face-to-face learning in terms of social competencies and it has not been the most preferred way of studying. Only 10% of international students prefer the 'online only' form of teaching, while blended learning is the most preferred mode, followed by face-to-face learning (Anthony et al., 2020; EDUCAUSE, 2020). Other studies show that according to students, online learning seems to be less effective in remote areas. This happens because communication networks and infrastructure do not adequately support them in online learning (Harefa, Sihombing, 2021) despite the steep penetration of IT tools in all spheres of activity (Remeikiene et al., 2021; Roshchyk et al., 2022). In this regard, successful forms of studying are connected with efforts aimed at finding the balance between online and traditional learning (Jackson & Konczos Szombathelyi, 2022).

The study conducted by Jena (2015) shows that e-learning causes burnout, decreases engagement in learning, results in poor academic performance, and increases intentions to withdraw. During the pandemic and other emergency e-learning situations, the majority of colleges and universities have experienced virtual learning problems (Harefa, Sihombing, 2021; Talidong, Toquero, 2020).

This can lead to "technostress" – a term introduced by Brod (1984) - and defined as an inability to cope with the new computer world technologies in an unhealthy manner. More recent definitions say it is the negative impact of technology on end-users (Tarafdar et al., 2019) or the problem of adaptation that an individual experiences when one is unable to cope with new technology (Upadhyaya,Vrinda, 2021). Several years ago, the problems associated with the use of technology changed from predominantly physical, such as carpal tunnel inflammation, to mental. People began to suffer from mental health problems, e.g., phantom vibration syndrome (Rosenberger, 2015; Shatrughan, 2017) to insomnia due to frequently using screens or classic smartphone addiction (Billieux et al., 2015; Fernández-Villa et al., 2015; Perez et al., 2012; Shechter et al., 2018). The FOMO syndrome may also be mentioned. The acronym comes from the English "Fear of Missing Out", and describes the fear that we may miss something going on in the world. According to Tarafdar et al. (2007). technostress is a multidimensional phenomenon encompassing five components, such as: techno-overload, techno-invasion, techno-complexity, techno-insecurity, and techno-uncertainty More technostress was observed in 2020 compared to previous years (Alvarez-Risco et al., 2021).

RESEARCH GAP

The research on technostress has mainly been focused on the governmental and business sectors (e.g. Ayyagari et al., 2011; Fuglseth, Sørebø, 2014). Also various studies in technostress related to various groups like employees, knowledge workers, employees in their early retirement and older adults (Rasticova et al., 2022). However, given the dynamic changes in the recent years modernizing learning and teaching via ICT (Wang, Li, 2019), this phenomenon should be also a point of research interest in higher education.

Technostress has been reported among university teachers (Estrada-Muñoz et al., 2021; Penado Abilleira et al, 2021) during the COVID-19 pandemic; however, limited research has investigated this issue among the younger generation, in particular university students (Alvarez-Risco et al., 2021; Upadhyaya, Vrinda, 2021). Furthermore, technostress results in psychological and behavioral strains (e.g., academic performance, satisfaction, commitment) among students, that is why it is of great importance to consider this phenomena during "forced" online learning in pandemic (Kader et al., 2020; Qi, 2019).

According to Aziz et al. (2021), university students are often perceived as digital natives and technologically savvy, and are thus expected to be free from technostress (Qi, 2019a; Setyadi et al., 2017). Paradoxically, Alexa (2022) revealed that they still have problems harnessing e-learning's advantages and integrating them into their study routine. Also, a study of Oladosu et al. (2020) noticed that because students use smart devices they become more technostressed, and this has a negative influence on their learning process. Technostress among students from different countries may be of great concern considering the increasing digitalization of everyday life makes it a cultural norm to use mobile smart devices in daily endeavors (Lepp et al., 2013).

As technostress constitutes emerging challenges for students and HEIs' management around the globe, this conceptual paper aims to take a closer look at the possible negative but also positive effects of remote learning on students' strain and motivation. To this end, as a theoretical background, we use the Job Demands-Resources framework (Bakker, Demerouti, 2017) - one of the most widely used stress models adapted to many organizational contexts. Although JD-R was proposed in the work context (Bakker, Demerouti, 2017; Lesener et, 2019) this model was also successfully used in educational settings (Salanova et al., 2010; Salmela-Aro, 2014; Schaufeli et al., 2002; Stubb et al., 2011; Mahapatra, Pati, 2018) and several previous studies provide evidence that the JD-R theory is a useful framework when analyzing the situation of students (Calderwood, Gabriel, 2017; Clements, Kamau, 2018; Ouweneel et al., 2011; Teuber et al., 2020; Wolff et al., 2014; Zeijen et al., 2021), but has also been used to explain technostress among employees (Mahapatra, Pati, 2018).

In general, the Job Demands-Resources theory postulates that all environmental characteristics can be categorized as job demands or job resources. Job demands are responsible for the health impairment process that leads to energy depletion and strain, whereas job resources initiate a motivational process that leads to well-being and flourishing. In detail, job resources are all "(…) those physical, psychological, social, or organizational aspects of the job that are functional in achieving work goals, reducing job demands and the associated physiological and psychological costs, or stimulating personal growth, learning, and development" (Bakker, Demerouti, 2017; p.274).

In contrast, job demands refer to "(…) those physical, psychological, social, or organizational aspects of the job that require sustained physical and/or psychological effort and are therefore associated with certain physiological and/or psychological costs" (Bakker, Demerouti, 2017, p.274). In the remote learning context, demands and resources might be understood as study demands and study resources that arise not from the job but the study in the computer and online environment. Moreover, the various aspects of technostress are important for our discussion. LePine et al. (2005) suggests that a distinction must be made between hindrance and challenge job demands. Hindrance demands refer to those circumstances that create undesirable constraints hampering the attainment of valued goals, e.g., remote learning software malfunctions, whereas challenge demands are defined as circumstances that require effort and create particular costs but also have the potential to stimulate achievement, personal growth, and development, e.g., time pressure to learn new computer skills (see Bakker, Demerouti, 2017; Cavanaugh et al., 2000; Podsakoff et al., 2007). In summary, the JD-R model states that good health and well-being result from a balance between various environmental characteristics. Resources provide students with energy and facilitate study-goal attainment, hindrance demands create obstacles in goal attainment and generate psychophysiological costs, and challenge demands, although they might generate certain costs, lead to personal development and growth.

Due to the increasing role of technology in university teaching and learning during COVID-19, many studies have pointed to the advantages (resources) and disadvantages (demands) of remote learning for students, but in our view, there is still a lack of theoretical integration of various positive and negative effects and that might lead to a better theoretical understanding of the psychological effect of remote learning on students. Therefore, we believed that our attempt might contribute to a better understanding of the conditions in which technostress might have positive and negative impacts on students.

We can pose the question of perception of technostress from a resources perspective, taking into account students as stakeholders of HEIs. In the literature on the subject of technostress, there are more disadvantages or demands (Li, Wang, 2021; Penado Abilleira et al., 2021; Upadhyaya, Vrinda, 2021). By definition, stress is usually interpreted as something negative (Grummeck-Braamt et al., 2021). In HEIs, as in many other sectors, the COVID-19 pandemic was the catalyst of change towards online education but also technostress (Boyer-Davis, 2020; Galvin et al., 2021; Penado Abilleira et al., 2021). However, the research also includes the concept of eustress, i.e., moderate or normal psychological stress interpreted as being beneficial for the experience. In this sense, technostress plays a mobilizing, innovative, and ground-breaking role, leading to a more effective learning and teaching processes (Li, Wang, 2021; Qi, 2019a; Upadhyaya, Vrinda, 2021). The mobilizing role is associated with the need to learn new forms of remote education, acquire the skills to use information and communication tools, and shape cooperative attitudes with the use of e-learning platforms. Such motivation to implement change requires effort and self-discipline from all stakeholders.

From the perspective of students, several advantages of online learning may be highlighted. First of all, online education allows students to acquire new digital competencies that will give them a competitive advantage in the labor market transforming toward telework. Due to these reasons, students are even ready to change their country of study trying to master more advanced skills (Mishchuk et al., 2019) paying attention to university

development tendencies in the perception of higher education quality (Draskovic et al., 2020). Second, online studying is perceived as very comfortable and convenient because of remote access to educators and materials. Third, it gives the possibility of easy and quick assessment together with a more personalized learning process. Fourth, there are much fewer time limits for student learning (Agarwal, Kaushik, 2020). Moreover, the study of Bączek et al., (2021), pointed to some positive effects of online learning such as: learning at own pace, the ability to stay at home in comfortable surroundings, easy access to online materials.

Remote learning does not allow significant control over the student in the learning and examination processes, which is a source of stress, but at the same time it requires changes and innovations about known and established teaching methods. The use of the possibility of learning in virtual groups, and remote implementation of exercises and tasks leads to the acquisition of new skills. Academic teachers learn to work and do virtual teaching, and students are better prepared to work in the virtual world. By following the trends in the global labor market, it is highly probable that the role of teleworking will become more and more significant in the future and that digital competencies of this kind will serve the development of graduates' careers. The key positive factor is time-saving and lower costs of remote learning compared to traditional ones.

In summary, technostress is a multi-dimensional construct with both negative but as well positive consequences (Ahmad et al., 2014; Wang et al., 2020). Technostress can also take the form of eustress, where students feel motivated by the need to learn new forms of work but are aware of the significant benefits associated with implementing new organizational forms (Shirish et al., 2021; Tarafdar et al., 2019; Weems-Landingham, 2021). It creates innovation in learning processes, saves the time of students, potentially lowers the cost of education, and makes it more accessible from a logistical point of view.

The literature on the subject also provides evidence that several demands lead to technostress for students. Wang et al. (2020) presented five demands that constituted technostress, including techno-overload (ICTs force employees to work faster and longer), techno-invasion, techno-complexity (intensity of social media used during COVID, fear of software malfunction), and techno-insecurity and techno-uncertainty (uncertainty/fear of losing jobs, either because of automation from ICTs or to other people who have a better understanding of ICTs). These stressors may lead to several unintended responses, including work overload, decreased engagement in the organization, reduced job satisfaction, lower productivity, , role ambiguity and role conflict, (Ayyagari et al., 2011; Tarafdar et al., 2011; Tu et al., 2005).

The extensive use of mobile devices by students causes the development of technostress and negatively influences their academic performance and productivity (Essel et al., 2021; Upadhyaya, Vrinda, 2021) because the technological overload and long-term online activity cause exhaustion that affects their capacity to complete homework and study for tests (Alvarez-Risco et al., 2021). Sethi et al. (2022) noticed recently that sessions including excercises, interactions, team projects, discussions, assignments, and examinations have gone online, and this has started in the compulsion of spending more time with technology and digital devices (laptops, mobile phones, desktops, etc.) Raza et al. (2019) added that also cyberbullying, and media multitasking hurt student performance during this forced emergency remote teaching. Al-Abdullatif et al. (2020) found the invasive effect of ICTs on students, and their need to be constantly connected, has a negative effect on their academic

writing skills, including clarity, vocabulary, accuracy, cohesiveness. Additionally, Verkijka (2019) noticed that technostress even had a direct negative influence on both the adoption and continuance of use of digital textbooks by students.

According to Mahapatra and Pati (2018) the complexity associated with ICTs leads to feel inadequate about their computer skills and forces the users to intensify their efforts in learning and understanding it. This specific techno demand negatively affected students' satisfaction and performance expectancy. Thus, reducing the fear of techno-malfunctions could help students to achieve better academic results (Abd Aziz et al., 2021).

Schettino et al. (2022) noticed that technostress can be seen as a risk factor both for students' perceptions of finding a job and for their well-being, but in other study (Choi, Lim, 2016), the social and information technology overload had no direct influence on psychological well-being.

In the study of Baabdullah et al. (2022), students were expected to spend more effort and time developing new skills and competencies in order to cope better with remote learning. This would be another source of stress, hindering the benefits yielded from using various learning applications, and therefore students would be less likely to have positive learning experiences. They also observed a positive correlation between technostress with students' emotional exhaustion.

Considering other psychological outcomes, Zhao et al. (2021) noticed that university students' technostress significantly predicted their learning burnout and that ICT competence alone had no significant effects on technostress. Moreover, administration support seemed to be essential in alleviating students' technostress and burnout. In other study based on gender it was found that females benefited more from support offered by the administration staff in easing learning burnout than males. In contrast, males benefit more from peer support in improving their ICT competence than females. Similarly, according to Upadhaya (2021), female students experienced higher levels of techno-complexity. Higher levels of technostress appeared also among older students, postgraduates, and students with lesser ICT experience.

There are also other students' individual differences, like mobile technology self-efficacy and the extent of ICT usage which may significantly influence technostress (Qi, 2019). Interestingly, Wiyajanti et al. (2021) conducted their research among business students in Indonesia and they noticed that the level of technostress of each individual is different and depends on religious orientation and level of psychological capital (PsyCap). This study suggests that intrinsic religious orientation and PsyCap can encourage individuals to endure challenges and rising demands, thereby reducing the stress caused by technology.

CONCEPTUAL INTEGRATION OF REMOTE LEARNING DEMANDS AND RESOURCES IN TECHNOSTRESS FORMATION

What may be understood from the above-mentioned research studies is that remote learning could have dual effects on students by creating demands and generating technostress, but it also might create positive stress in the form of so-called eustress when remote learning, despite being energy-draining, motivates student to self-develop and learn new competencies. To reconcile this different view on remote learning, i.e., either as a stress generator or as a

motivator for changes and development, in this paper, we draw from the Job Demands-Resources theory (JD-R) to better understand the effects of remote learning on students' well-being and strain.

We suggest that applying the JD-R theory to the remote learning 'technostress' phenomenon can help to build a conceptual model explaining how the positive and negative effects of technostress result from remote learning and what the mechanisms of its influence are on students' motivation and strain. On one hand, remote learning might be seen as a source of hindrance techno-demands, many difficulties that might impede progress in learning and negatively impact students' well-being (e.g., malfunction of the software, fear of missing important social activities when sitting at home instead of being at the campus, ineffective online lectures and classes, the unfairness of online exams, etc). On the other hand, remote learning might be seen as a source of techno-resources that facilitate learning (e.g., it might enable learning during a difficult time like a pandemic, save time due to limiting the need to commute, and allow the fast exchange of study materials, etc.). Moreover, drawing from the JD-R, we also suggest distinguishing not only positive, i.e., techno-resources, and negative, i.e. techno-demands, effects of remote learning but also a third category called techno-challenges. In line with research on human motivation and well-being, challenges are seen as those demanding circumstances that "cost effort but that potentially promote personal growth and achievement" (Bakker & Demerouti, 2017, p.277). For example, the need to learn how to use common online communication tools such as Zoom or MS Teams might require effort and cost energy and stress but at the same time might be seen as a motivating experience that leads to the development of new skills necessary in the future workplace. Thus, challenges such as the one described above might simultaneously spark motivation and drain energy. In line with this reasoning, recent studies describe the old concept of eustress (Cavanaugh et al., 2000; Le Fevre et al., 2006) as "positive" stress yielding in techno-eustress, i.e., stress arising from technology that is challenging and motivating (Califf et al., 2020; Chandra et al., 2019; Salazar-Concha et al., 2021; Tarafdar et al., 2019). Recent developments in technology enhancement learning during the COVID-19 pandemic have focused the attention of some researchers on techno-eustress that stems from remote learning. Shirish, Chandra, & Srivastava (2021), have shown that techno-eustress mediates the effect of remote learning on students' performance. In a remote learning context, techno-eustress might refer to a situation in which students perceive demands that stem from information technology as challenges rather than hindrances, thus in line with JD-R theoretical framework, techno-eustress is sparked by the challenging demands and techno-challenges.

Taking into account the various possible effects of remote learning on students, the question arises about what the total effect is of remote learning on students, and what factors might mediate the effect of remote learning on students. We suggest that using the JD-R theory as a theoretical framework might help to integrate the positive and negative effects of remote learning on students and gain insights into a better understanding of remote learning effects on students. We see this integrated approach as important because concentration only on the negative aspects of remote learning may blur the whole picture, only describing technostress caused by technology and transition to an online environment is the simplistic view when ignoring the positive effects of remote learning. The proposed model of the

effects of remote learning on students' motivation and performance that uses the JD-R theory to integrate different possible effects of remote learning is depicted in Figure 1.

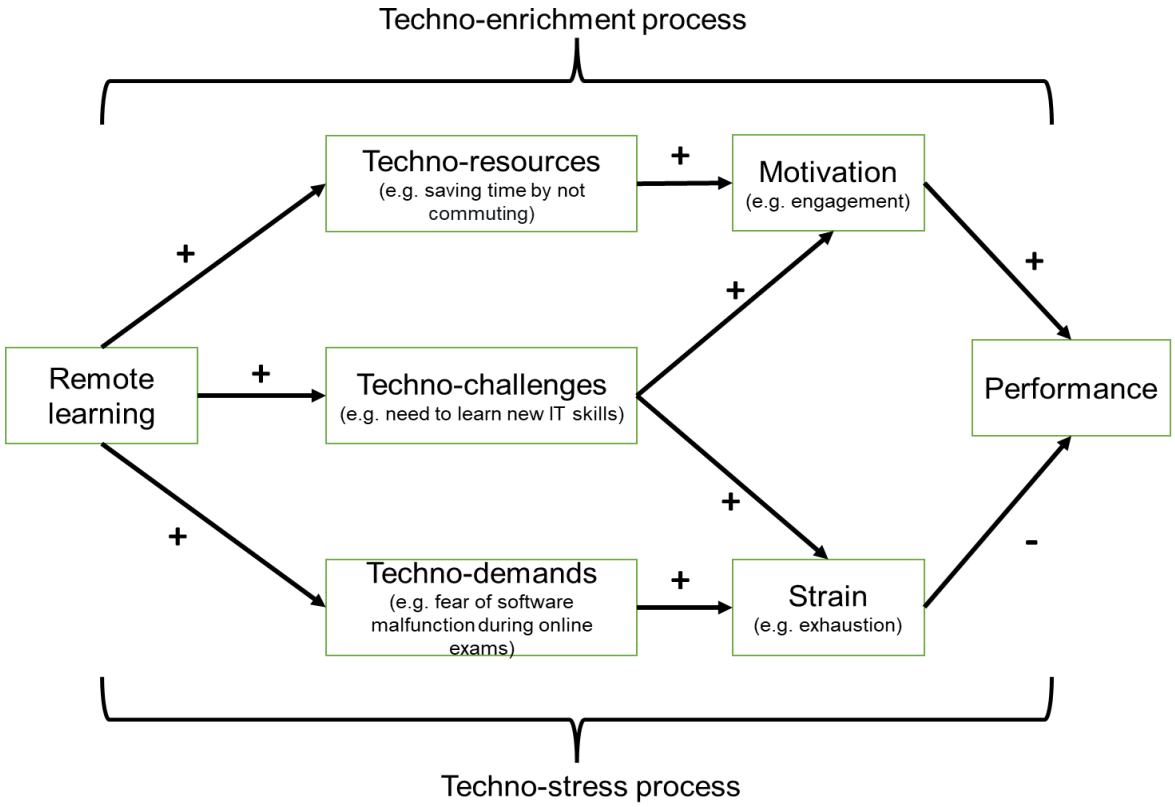

Figure 1. Model of remote learning effects on students' performance mediated by techno-resources, techno-challenges, and techno-demands inspired by the Job Demands-Resources theory. [Bakker & Demerouti, 2017]

The model of possible positive and negative effects of technostress presented in Figure 1 describes three possible effects of remote learning on a performance inspired by the JD-R model. It is important to note that we aim to propose an overreaching conceptual framework to understand students' technostress in different technological settings that is independent of particulates of technology used in remote learning. In other words, we suggest that concepts of techno-demands, techno-resources and techno-challenges although might be caused by different specific aspects of technology but on a conceptual level they are similar. E.g. techno-resources are those characteristics of the technology used in the study environment and learning process that help achieve valuable study goals and protect against hindrances and difficulties. As we are not limited to any particular technology, hardware or software, this approach allows establishing a common theoretical background that might be used to better understand students' experience during remote learning in different technological settings but also might spark further theoretical debates providing even more insights in study technostress experiences in remote learning.

First, in line with the JD-R theory, remote learning might generate techno-resources, i.e., social, physical, psychological, or organizational characteristics of the technology used in the study environment and learning process that help achieve valuable study goals, protect against hindrances and difficulties, and their physiological and psychological costs, or promote students learning, and personal development (see Bakker, Demerouti, 2017). Techno-resources that emerge from remote learning (e.g., time-saving on commuting, easy access to course materials) provide energy and increase motivation, thus improving study performance. We propose calling this path from remote learning via techno-resources to improved performance a techno-enrichment process.

Second, remote learning might generate techno-demands, which as adapted from the JD-R concept of job demands to the study environment, and might be described as physical, psychological, social, or organizational aspects of the technology used in the study environment and learning process that need long-lasting physical and/or psychological effort and are therefore generating specific physiological and/or psychological costs (see (Bakker, Demerouti, 2017). Techno-demands (e.g., fear of software malfunction during exams; lack of stable internet connection) drain energy and lead to the development of strain responses and consequently worsened study performance. We suggest calling this path from remote learning via techno-demands to diminished performance a techno-stress process.

Third, remote learning might also generate challenging study demands – techno challenges, that, based on Crawford, LePine, & Rich, (2010) and Bakker & Demerouti (2017), work in the scope of the JD-R model and might be defined as stressful demands steaming from the technology used in the study environment and learning process that have the potential to promote future growth of competency. Students tend to perceive these challenging demands as opportunities to, rather than as a hindrance or difficulty in the learning process. We suggest that techno-challenges that arise from remote learning might influence performance through techno-enrichment and techno-stress processes.

Our conceptual elaboration provides several contributions to a better understanding of the effect of remote learning on student technostress. First, based on the JD-R theory, a well-established model of strain and well-being, we provide a concise description of possible effects of stressors/demands on students that stem from technology. Second, we highlight that remote learning not only generates techno-demand leading to techno-stress but also might have positive effects via techno-resources and techno-challenges. Particularly remote learning might act as a challenging stressor that sparks eustress related to motivation and performance (Lepine et al., 2005). Third, our theoretical model, by highlighting three different results of remote learning, i.e., techno-demands, techno-challenges, and techno resources might help to reconcile conflicting experiences that stem from remote learning. Finally, the proposed theoretical model might not only explain the possible effects of remote learning on students, but also provide a guideline for research seeking an explanation for the mixed response to technology use in learning.

LIMITATIONS AND FURTHER STUDIES

Our model also opens some fruitful avenues for further research. One of them is the question of which aspects of remote learning might be seen as techno-resources, techno-challenges, and techno-demands. In other words, does remote learning have specific properties that for all students are universally challenging/demanding, or does the perception of challenges or demands depend on students' appraisal and coping mechanisms?

Another interesting question is the question of the role of academic staff in the formation of technostress, particularly to what extent academic teachers' and university managers' behavior and attitudes might moderate the effect of remote learning on students. For example, is it possible that under a supportive teacher the aspect of remote learning, e.g., the need to acquire new skills, is perceived by students as a techno-challenge, whereas under an unsupportive teacher the same aspect of remote learning becomes a hindrance to techno-demands?

An intriguing avenue for further research is also the role of techno-challenges, as they are known to be a double-edged sword (see e.g. Crawford et al., 2010). On one hand, they increase motivation, but simultaneously they are positively related to strain. It will be a challenge for further research to solve this puzzle and establish in what circumstances techno-challenges lead to positive effects on motivation and performance, outweighing the negative side effects in the form of energy depletion and strain.

Last but not least, artificial intelligence (AI) algorithms are emerging trends in remote learning. AI is a part of computer science that creates and develops machine systems able to demonstrate behaviors linked to human intelligence. AI algorithms are trained on big data sets from different sources to mimic humans to perform tasks such as learning, planning, knowledge representation, perception and problem-solving. AI technology is used for a wide range of applications, such as automated chatbots for customer service, product recommendations based on a user's habits or speech recognition. Essentially, the purpose of AI is to improve the systems people already use by automating tasks to make them more efficient (Wix Encyclopedia, 2022). At the same time, the usage of AI can cause or increase the risk of technostress. Lastly, the capability of Open AI (https://openai.com/blog/chatgpt/), chatGPT based on Generative Pretrained Transformer 3 (GPT-3) is causing a stir on the internet. To illustrate this we ask chatGPT a question "How remote learning might generate technostress among students?" This is a part of the answer generated by AI: *"(...)students may feel overwhelmed by the amount of information they are expected to learn and the need to constantly use technology to access that information. Additionally, students may feel frustrated if they are not familiar with the technology being used for remote learning, or if they do not have access to the necessary technology or support to fully participate in the remote learning experience. Furthermore, remote learning can also create a sense of isolation for students, as they may feel disconnected from their classmates and teachers".* Although this answer is not without flaws it illustrates the capabilities of AI algorithms to produce an imitation of a human-like response containing some thought-provoking ideas. As such we suggest that AI is creating a hotbed for techno-resources and techno-demands for students and teachers in remote learning. In this context, our model of the technostress might be also used to understand how AI will affect students in remote learning. E.g. in terms of

techno-demands, the rise of AI chats might spark uncertainty among students if they receive answers from a trusted source such as a teacher or from AI algorithms build into remote learning platforms. From the perspective of techno-resources, the AI algorithm might check for formal or grammar errors in student essays, leaving more room for concentration on creativity. From the techno-challenge perspective, the use of AI algorithms in remote learning needs a "paradigm shift" in education and openness to use technology in a new way not only as a mindless tool but as a learning facilitator with some capabilities similar to those of human teachers e.g grammatical error correction. AI is an emerging trend and we believe that our model might be used to gain better insights into AI effects on students' technostress in remote learning.

REFERENCES

Abd Aziz,N., Kader,M.A.R., Ab Halim, R. (2021). The Impact of Technostress on Student Satisfaction and Performance Expectancy. *Asian Journal of University Education* 17(4), 538-552. https://doi.org/10.24191/ajue.v17i4.16466

Abd Aziz, N. N., & Abu Yazid, Z. N. (2021). Exploratory Factor Analysis of Technostress among University Students. *International Journal of Academic Research in Progressive Education and Development*, *10*(3). https://doi.org/10.6007/ijarped/v10-i3/10396

Agarwal,S., Kaushik, J. S. (2020). Students' perception of online learning during Covid-19 pandemic. *The Indian Journal of Pediatrics*, *87*, 554.

Ahmad, U. N., Amin, S. M.,Ismail, W. K. W. (2014). Moderating effect of technostress inhibitors on the relationship between technostress creators and organisational commitment. *Sains Humanika*, *67*(1). 51-62

Al-Abdullatif,A., Alsubaie,M., Aldoughan, E. A. (2020). Exploring the Effects of Excessive Texting Through Mobile Applications on Students' Technostress and Academic Writing Skills in the Arabic Language. *IEEE Access*, *8*, 166940–166950. https://doi.org/10.1109/ACCESS.2020.3024021.

Alexa, L., Pislaru, M., Avasilcăi, S.,Lucescu, L., Bujor, A.,; Avram, E. . (2022). Exploring Romanian Engineering Students' Perceptions of Covid-19 Emergency e-Learning Situation. A Mixed-Method Case Study. *Electronic Journal of E-Learning*, *20*(1), 19–35.

Alvarez-Risco, A., Del-Aguila-Arcentales, S., Yáñez, J. A., Rosen, M. A., & Mejia, C. R. (2021). Influence of technostress on academic performance of university medicine students in peru during the covid-19 pandemic. *Sustainability (Switzerland)*, *13*(16). https://doi.org/10.3390/su13168949

Anthony, B., Kamaludin, A., Romli, A., Raffei, A. F. M., Phon, D. N. A. L. E., Abdullah, A., & Ming, G. L. (2020). Blended Learning Adoption and Implementation in Higher Education: A Theoretical and Systematic Review. In *Technology, Knowledge and Learning*. Springer Netherlands. https://doi.org/10.1007/s10758-020-09477-z

Ayyagari, R., Grover, V., Purvis, R. (2011b). Technostress: Technological Antecedents and Implications. *MIS Quarterly*, *35*(4), 831–858.

Baabdullah, A., Alsulaimani,A.A., Allamnakhrah, A., Alalwan,A.A., Dwivedi,Y., Rana, N. (2022). Usage of augmented reality (AR) and development of e-learning outcomes: An empirical evaluation of students' e-learning experience. *Computers & Education*, *177*. https://www.sciencedirect.com/science/article/abs/pii/S0360131521002608?msclkid=12e4918fb8b511ecbbd8e2ed746b03dd

Bączek,M., Zagańczyk-Bączek,M., Szpringer,M., Jaroszyński,A., Wożakowska-Kapłon, B. (2021). Students' perception of online learning during the COVID-19 pandemic A survey study of Polish medical students.

Medicine, *100*(7). e24821-e24821

Bakker, A. B., Demerouti, E. (2017). Job demands–resources theory: taking stock and looking forward. *Journal of Occupational Health Psychology*, *22*(3), 273-285.

Billieux, J., Maurage, P., Lopez-Fernandez, O., Kuss, D. J., Griffiths, M. D. (2015). Can disordered mobile phone use be considered a behavioral addiction? An update on current evidence and a comprehensive model for future research. *Current Addiction Reports*, *2*(2), 156–162.

Boyer-Davis, S. (2020). Technostress in higher education: An examination of faculty perceptions before and during the COVID-19 pandemic. *Journal of Business and Accounting*, *13*(1), 42–58.

Brod, C. (1984). *Technostress: The Human Cost of The Computer Revolution*. Addison Wesley Publishing Company.

Calderwood, C., Gabriel, A. S. (2017). Thriving at school and succeeding at work? A demands-resources view of spillover processes in working students. *Journal of Vocational Behavior*, *103*, 1–13.

Califf, C. B., Sarker, S., & Sarker, S. (2020). The Bright and Dark Sides of Technostress: A Mixed-Methods Study Involving Healthcare IT. *MIS Quarterly*, *44*(2). 809-856

Cavanaugh, M. A., Boswell, W. R., Roehling, M. V., Boudreau, J. W. (2000). An empirical examination of self-reported work stress among U.S. managers. *Journal of Applied Psychology*, *85*(1), 65–74.

Chandra, S., Shirish, A., Srivastava, S. C. (2019). Does technostress inhibit employee innovation? Examining the linear and curvilinear influence of technostress creators. *Communications of the Association for Information Systems*, *44*(1), 19. 299-331

Choi,S.B., Lim, M. (2016). Effects of social and technology overload on psychological well-being in young South Korean adults: The mediatory role of social network service addiction. *Computers in Human Behavior*, *61*, 245–254.

Clements, A. J., Kamau, C. (2018). Understanding students' motivation towards proactive career behaviours through goal-setting theory and the job demands–resources model. *Studies in Higher Education*, *43*(12), 2279–2293.

Crawford, E. R., LePine, J. A., Rich, B. L. (2010). Linking job demands and resources to employee engagement and burnout: a theoretical extension and meta-analytic test. *Journal of Applied Psychology*, *95*(5), 834–848.

Draskovic, V., Jovovic, R., & Rychlik, J. (2020). Perceptions of the declining quality of higher education in the selected SEE countries. *Journal of International Studies*, *13*(4), 286-294. doi:10.14254/2071-8330.2020/13-4/20

EDUCAUSE. (2020). *Horizon Report.Teaching and Learning Edition*. https://doi.org/https://library.educause.edu/-/media/files/library/2020/3/2020_horizon_report_pdf

Essel,H., Vlachopoulos,D., Tachie-Menson,A., Johnson,E., Ebeheakey, A. (2021). Technology-Induced Stress, Sociodemographic Factors, and Association with Academic Achievement and Productivity in Ghanaian Higher Education during the COVID-19 Pandemic. *Information*, *12*(12), 1–17.

Estrada-Muñoz, C., Vega-Muñoz, A., Castillo, D., Müller-Pérez, S., & Boada-Grau, J. (2021). Technostress of chilean teachers in the context of the covid-19 pandemic and teleworking. *International Journal of Environmental Research and Public Health*, *18*(10). https://doi.org/10.3390/ijerph18105458

Fernández-Villa, T., Ojeda, J. A., Gómez, A. A., Carral, J. M. C., Delgado-Rodríguez, M., García-Martín, M., Martín, V. (2015). Uso problemático de internet en estudiantes universitarios: factores asociados y diferencias de género. *Adicciones*, *27*(4), 265–275.

Fuglseth, A. M., Sørebø, Ø. (2014). The effects of technostress within the context of employee use of ICT. *Computers in Human Behavior*, *40*, 161–170.

Galvin, J., Evans, M. S., Nelson, K., Richards, G., Mavritsaki, E., Giovazolias, T., ... & Vallone, F. (2021).

Technostress, coping, and anxious and depressive symptomatology in university students during the COVID-19 pandemic. *Europe's Journal of Psychology*. 18(3), 302-318

Grummeck-Braamt, J. V., Nastjuk, I., Najmaei, A., Adam, M. (2021). A bibliometric review of technostress: Historical roots, evolution and central publications of a growing research field. *Proceedings of the 54th Hawaii International Conference*, 6621.

Harefa, S., & Sihombing, G. L. A. (2021). Students' perception of online learning amidst the Covid-19 pandemic: A study of junior, senior high school and college students in a remote area. *F1000Research, 10*, 867. https://doi.org/10.12688/f1000research.52152.1

Jackson, K., & Konczos Szombathelyi, M. (2022). The influence of COVID-19 on sentiments of higher education students - prospects for the spread of distance learning. *Economics and Sociology*, *15*(3), 216-247. doi:10.14254/2071- 789X.2022/15-3/13

Jena, R. K. (2015). Technostress in ICT enabled collaborative learning environment: An empirical study among Indian academician. *Computers in Human Behavior*, *51*, 116–1123.

Kulikowski, K., Przytuła, S., Sułkowski, Ł. (2021a). E-learning? Never again! On unintended consequences of COVID-19 forced e-learning on academic teacher motivational job characteristics. *Manuscript Submitted for Publication*. 76(1), 174-189.

Kulikowski, K., Przytuła, S., Sułkowski, Ł. (2021b). Emergency forced pandemic e-learning - feedback from students for HEI's management. *Journal of Open and Distance Learning*, *36*(3), 245–262.

Le Fevre, M., Kolt, G. S., Matheny, J. (2006). Eustress, distress and their interpretation in primary and secondary occupational stress management interventions: Which way first? *Journal of Managerial Psychology*, *21*(6), 547–565.

Lepine, J. A., Podsakoff, N. P., Lepine, M. A. (2005). A meta-analytic test of the challenge stressor-hindrance stressor framework: An explanation for inconsistent relationships among stressors and performance. *Academy of Management Journal*, *48*(5), 764–775.

Lepp, A., Barkley, J. E., Sanders, G. J., Rebold, M., Gates, P. (2013). The relationship between cell phone use, physical and sedentary activity, and cardiorespiratory fitness in a sample of US college students. *International Journal of Behavioral Nutrition and Physical Activity*, *10*(1), 79–90.

Lesener, T., Gusy, B., Wolter, C. (2019). The job demands-resources model: A meta-analytic review of longitudinal studies. *Work & Stress*, *33*(1), 76–103.

Li, L., Wang, X. (2021). Technostress inhibitors and creators and their impacts on university teachers' work performance in higher education. *Cognition, Technology & Work*, *23*(2), 315–330.

Mahapatra,M., Pati, S. (2018). Technostress creators and burnout: A Job Demands-Resources Perspective. In D. Kishore,R., Beimborn (Ed.), *SIGMIS-CPR'18: Proceedings of the 2018 ACM SIGMIS Conference on Computers and People Research*. Association for Computing Machinery. https://doi.org/https://dl.acm.org/doi/proceedings/10.1145/3209626

Mishchuk, H., Roshchyk, I. Sułkowska, J. & Vojtovič, S. (2019). Prospects of Assessing the Impact of External Student Migration on Restoring the Country's Intellectual Potential (Case Study of Ukraine). *Economics & Sociology*, 12(3), 209-219. DOI: 10.14254/2071-789X.2019/12-3/14

Oladosu, K. K., Alasan, N. J., Ibironke, E. S., Ajani, H. A., & Jimoh, T. A. (2020). Learning with Smart Devices: Influence of Technostress on Undergraduate Students' Learning at University of Ilorin, Nigeria. *International Journal of Education and Development Using Information and Communication Technology (IJEDICT)*, *16*(2), 40–47.

Ouweneel, E., Le Blanc, P. M., Schaufeli, W. B. (2011). Flourishing students: A longitudinal study on positive emotions, personal resources, and study engagement. , 6(2),. *The Journal of Positive Psychology*, *6*(2), 142–153.

Penado Abilleira, M.; Rodicio-García, M.L.; Ríos-de Deus, M.P.; Mosquera-González, M. J. (2021).

Technostress in Spanish University Teachers During the COVID-19 Pandemic. *Frontiers in Psychology*, *12*. 617650

Perez, E. J., Pedrero, María Teresa, R. M., Jose María, R. S., León, D. (2012). Mobile phone abuse or addiction. A review of the literature. *Adicciones*, *24*(2). www.proquest.com/scholarly-journals/mobile-phone-abuse-addiction-review-literature/docview/1609096959/se-2?accountid=28016

Podsakoff, N. P., LePine, J. A., LePine, M. A. (2007). Differential challenge stressor-hindrance stressor relationships with job attitudes, turnover intentions, turnover, and withdrawal behavior: A meta-analysis. *Journal of Applied Psychology*, *92*(2), 438–454.

Qi, C. (2019). A double-edged sword? Exploring the impact of students' academic usage of mobile devices on technostress and academic performance. *Behaviour & Information Technology*, *12*, 1337–1354.

Rasticova,M., Lakomy,M., Sacha,J., Sobotkova, E. (2022). Technostress among older workers in selected EU countries. *Cyberpsychology:Journal of Psychosocial Research on Cyberspace*.

Rayan, A.; Dadoul, A.M.; Jabareen, H.; Sulieman, Z.; Alzayyat, A.; Baker, O. (2017). Internet Use among University Students in South West Bank: Prevalence, Advantages and Disadvantages, and Association with Psychological Health. *International Journal of Mental Health and Addiction*, *15*, 118–129.

Raza,M., Khan,A., Khan,N., Ali,A., Bano, S. (2019). Dark side of social media and academic performance of public sector schools students: Role of parental school support. *Journal of Public Affairs*. e2058

Remeikiene, R., Gaspareniene L., Fedajev, A., & Vebraite, V. (2021). The role of ICT development in boosting economic growth in transition economies. *Journal of International Studies, 14*(4), 9-22. doi:10.14254/2071-8330.2022/14-4/1

Rosenberger, R. (2015). An experiential account of phantom vibration syndrome. *Computers in Human Behavior*, *52*, 124–131.

Roshchyk, I., Oliinyk, O., Mishchuk, H., Bilan, Y. (2022). IT Products, E-Commerce, and Growth: Analysis of Links in Emerging Market. *Transformations in Business & Economics*, *21*(1), 209-227.

Salanova, M., Schaufeli, W., Martinez, I., Breso, E. (2010). How obstacles and facilitators predict academic performance: the mediating role of study burnout and engagement. *Anxiety, Stress, and Coping*, *23*(1), 53–70.

Salazar-Concha, C., Ficapal-Cusí, P., Boada-Grau, J., Camacho, L. J. (2021). Analyzing the evolution of technostress: A science mapping approach. *Heliyon*, *7*(4). e06726

Salmela-Aro, K., Upadyaya, K. (2014). School burnout and engagement in the context of demands-resources model. *The British Journal of Educational Psychology*, *84*, 137–151.

Schaufeli, W. B., Martinez, I. M., Pinto, M., Salanova, M., Bakker, B. (2002). Burnout and Engagement in University Students: A Cross-National Study. *Journal of Cross-Cultural Psychology*, *33*(5), 464–481.

Schettino,G., Marino,L., Capone, V. (2022). The Impact of University-Related Variables on Students' Perceived Employability and Mental Well-Being: An Italian Longitudinal Study. *Sustainability*, *14*(5), 1–15.

Sethi,D., Pereira,V., Vikas, A. (2022). Effect of Technostress on Academic Productivity: E-Engagement Through Persuasive Communication. *Journal of Global Information Management*, *30*(5). 1-19.

Setyadi, H. J., Widagdo, P. P., Susanto, T. D. (2017). Cognitive age and chronological age of the technostress that effect on satisfaction, performance, and intention of continue the use of information technology in the university. *Proceeding - 2017 3rd International Conference on Science in Information Technology: Theory and Application of IT for Education, Industry and Society in Big Data Era*, 330–335. https://doi.org/https://doi.org/10.1109/ICSITech.2017.8257134

Shatrughan, P. (2017). Phantom Vibration Syndrome: An Emerging Phenomenon. *Asian Journal of Nursing Education and Research*, *7*(4), 596–597.

Shechter, A., Kim, E. W., St-Onge, M. P., Westwood, A. J. (2018). Blocking nocturnal blue light for insomnia:

A randomized controlled trial. *Journal of Psychiatric Research*, *96*, 196–202.

Shirish, A., Chandra, S., Srivastava, S. C. (2021). Switching to online learning during COVID-19: Theorizing the role of IT mindfulness and techno eustress for facilitating productivity and creativity in student learning. *International Journal of Information Management*, *61*, 102394.

Stubb, J., Pyhältö, K., Lonka, K. (2011). Balancing between inspiration and exhaustion: PhD students' experienced socio-psychological well-being. *Studies in Continuing Education*, *33*(1), 33–50.

Sun, Y.; Li, Y.; Bao, Y.; Meng, S.; Sun, Y.; Schumann, G.; Kosten, T.; Strang, J.; Lu, L.; Shi, J. (2020). Brief report: Increased adictive iternet and sbstance use behavior during the COVID-19 pandemic in China. . 2020, 29,. *The American Journal on Addiction*, *29*, 268–270.

Talidong, K.J., Toquero, C. M. . (2020). Philippine Teachers' Practices to Deal with Anxiety amid COVID-19. *Jourrnal of Loss Trauma*, 1–8.

Tarafdar, M., Cooper, C. L., Stich, J. F. (2019). The technostress trifecta – techno eustress, techno distress and design: Theoretical directions and an agenda for research. *Information Systems Journal*, *29*(1), 6–42.

Tarafdar, M., Tu, Q., Ragu-Nathan, B. S., Ragu-Nathan, T. S. (2007). The Impact of Technostress on Role Stress and Productivity. *Journal of Management Information Systems*, *24*(1), 301–328.

Tarafdar, M., Tu, Q., Ragu-Nathan, T. S., Ragu-Nathan, B. S. (2011). Crossing to the Dark Side: Examining Creators, Outcomes, and Inhibitors of Technostress. *Communications of the ACM*, *54*(9), 113–120.

Teuber, Z., Nussbeck, F. W., Wild, E. (2020). The Bright Side of Grit in Burnout-Prevention: Exploring Grit in the Context of Demands-Resources Model among Chinese High School Students. *Child Psychiatry & Human Development*, 1–13.

Tu, Q., Wang, K., Shu, Q. (2005). Computer-related Technostress in China. *Communications of the ACM*, *48*(4), 77–81.

Upadhyaya, P., & Vrinda. (2021). Impact of technostress on academic productivity of university students. *Education and Information Technologies*, *26*(2), 1647–1664. https://doi.org/10.1007/s10639-020-10319-9

Verkijika, S. (2019). Digital textbooks are useful but not everyone wants them: The role of technostress. *Computers & Education*, *140*. 103591

Wang, X., Tan,C., Li, L. (2020). Technostress in university students' technology-enhanced learning: An investigation from multidimensional person-environment misfit. *Computers in Human Behavior*, *105*. 106208

Wang, X., & Li, B. (2019). Technostress among teachers in higher education: An investigation from multidimensional person-environment misfit. *Frontiers in Psychology*, *10*(JULY). https://doi.org/10.3389/fpsyg.2019.01791

Weems-Landingham, V. (2021). Embracing Technostress to Overcome Online Teaching Challenges. *AURCO Journal*, *27*, 30–40.

Wijayanti,D.M., Riza, A., Casmini, M. . ; M. ; (2021). The Role of Religious Orientation and PsyCap in Mitigating Technostress. *Journal of Management, Spirituality & Religion*, *18*(5), 358–374.

Wix Encyklopedia, (2022). Artificial Intelligence (AI). https://www.wix.com/encyclopedia/definition/artificial-intelligence

Wolff, W., Brand, R., Baumgarten, F., Lösel, J., Ziegler, M. (2014). Modeling students' instrumental (mis-) use of substances to enhance cognitive performance: Neuroenhancement in the light of job demands-resources theory. *BioPsychoSocial Medicine*, *8*(1), 1–11.

Zeijen, M. E., Brenninkmeijer, V., Peeters, M. C., Mastenbroek, N. J. (2021). Exploring the Role of Personal Demands in the Health-Impairment Process of the Job Demands-Resources Model: A Study among Master Students. *International Journal of Environmental Research and Public Health*, *18*(2), 632

Zhao, G., Wang, Q., Wu, L., Dong, Y. (2021). Exploring the Structural Relationship Between University Support, Students' Technostress, and Burnout in Technology-enhanced Learning. *The Asia-Pacific Education Researcher*. https://doi.org/10.1007/s40299-021-00588-4

Authors' Note

All correspondence should be addressed to:
Konrad Kulikowski
University of Social Sciences
Sienkiewicza 9, 90-113 Łódź, Poland
kkulikowski@san.edu.pl

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

Human TECHNOLOGY

ISSN: 1795-6889

https://ht.csr-pub.eu Volume 18(3), December 2022, 250-266

SEGMENTATION BOUNDARIES IN ACCELEROMETER DATA OF ARM MOTION INDUCED BY MUSIC: ONLINE COMPUTATION AND PERCEPTUAL ASSESSMENT

Juan Ignacio Mendoza G.
University of Jyväskylä
Department of Music, Art and Culture Studies
Finland

Abstract: *Segmentation is a cognitive process involved in the understanding of information perceived through the senses. Likewise, the automatic segmentation of data captured by sensors may be used for the identification of patterns. This study is concerned with the segmentation of dancing motion captured by accelerometry and its possible applications, such as pattern learning and recognition, or gestural control of devices. To that effect, an automatic segmentation system was formulated and tested. Two participants were asked to 'dance with one arm' while their motion was measured by an accelerometer. The performances were recorded on video, and manually segmented by six annotators later. The annotations were used to optimize the automatic segmentation system, maximizing a novel similarity score between computed and annotated segmentations. The computed segmentations with highest similarity to each annotation were then manually assessed by the annotators, resulting in Precision between 0.71 and 0.89, and Recall between 0.82 to 1.*

Keywords: *gestural interface, perceptual evaluation, temporal segmentation, accelerometer, bodily motion, similarity*

DOI: https://doi.org/10.14254/1795-6889.2022.18-3.4

INTRODUCTION

The advancement in miniaturization of accelerometers, gyroscopes and magnetometers has made it possible to develop portable and wearable systems that sense the movement of the human body. This has opened doors for many applications in a vast range of domains. Many such applications require identifying segmentation boundaries within movement, that is, where data changes from one regime to another. Following this, the detected segments can be classified or clustered. Some methods detect segmentation boundaries in the same process that performs classification or clustering. Examples of applications that use these processes include systems for detecting, recognizing and monitoring activities for clinical diagnosis or assisting in sports training (Cornacchia, Ozcan, Zheng, &Velipasalar, 2017).

The focus of the current study was to identify segmentation boundaries within the movement of a person dancing. In a practical application, the detected segmentation boundaries may be used to control playback of sound, music or lighting, for example. The movement of the dancer may be sensed in a number of different ways, but this study focuses on the use of a single triaxial accelerometer. The output is the time when a segmentation boundary has occurred, with respect to real time. Then, this information may be used for the control of a separate process (e.g., triggering events) or for machine-learning processes such as clustering or classification of the found segments.

It is desirable that the result of the segmentation system is produced fast enough for near-real-time interaction. Also, it is necessary that the motion segments are meaningful to an observer. In other words, motion segments produced by the system should match the segments perceived by an observer. The meaningfulness of motion segments would additionally facilitate the learning of motion patterns and mappings to audio or visual effects. To that extent, it must be acknowledged firstly, that human perception of bodily movement is highly subjective (Bläsing, 2015; Kahol, Tripathi, & Panchanathan, 2004; Zacks, Kumar, Abrams, & Mehta, 2009) and is hierarchically structured such that short patterns are grouped into larger ones (Bernard, Dobermann, Vögele, Krüger, Kohlhammer, & Fellner, 2017; Dreher, Kulp, Mandery, Wächter, & Asfour, 2017; Krüger, Kragic, Ude, & Geib, 2007; Lin, Karg, & Kulić, 2016). Also, it must be taken into consideration that dance patterns may or may be not repetitive. Thus, the system must be capable of detecting repetitive and non-repetitive patterns, and must allow the user to make adjustments to obtain perceptually meaningful results.

The algorithm described by Foote (2000) for segmentation of digital audio was found to be an appropriate candidate for segmentation of dance movement. This algorithm has subsequently been used for segmentation of video (Foote & Cooper, 2003), and of dance motion based on speed extracted from video (Tardieu et al., 2009). It has also been used to identify boundaries between activities such as walking, jogging and sitting, in single-axis accelerometer data (Rodrigues, Probst, & Gamboa, 2021). While most published implementations are online (i.e., data is processed serially as it is input to the algorithm), Schätti (2007) described an online implementation for segmentation of an audio signal. Also these implementations have been tested on data whose segments span several seconds or minutes (e.g., sections of a song, walking). Therefore, the current study has focused on the adaptation of an online version of the algorithm to work with a triaxial accelerometer signal, and the assessment of its capability to meet the requirements of the intended application. The

contributions of the present study are, first, the application and testing of the segmentation algorithm at a smaller time-scale (i.e., short dancing patterns spanning a few seconds), and a more robust perceptual assessment than those used in previous work. The second contribution is a novel measure to evaluate the similarity between computed and perceived segmentation boundaries.

This report is structured as follows: The remainder of the introduction presents a succinct review of the state-of-the-art methods that most closely meet the requirements stated above, including unsupervised near-real-time detection of segmentation boundaries, boundaries of self-similarity checkerboard patterns, and assessments of effectiveness. In favor of a timely report, a comprehensive comparison of different techniques is out of the scope of this study. Following this, the Methods utilized and the Results so obtained are reported. Finally, the Conclusion provides a summary of the study, including directions for future work.

Unsupervised Near-Real-Time Detection of Segmentation Boundaries

Several algorithms that detect segmentation boundaries and give results in near-real-time have been tested with data from accelerometers. For example, Gharghabi et al. (2019) described a method that evaluates the similarity in shape –but not in statistical properties– between all fixed-length windows within a bigger window, the length of which is specified by the user. A segmentation boundary is recorded where the similarity is minimal. This method assumes that each segment will be composed of at least two instances of a periodic motion.

Another approach is to pose the task as a multivariate change-point detection problem (Endres, Christensen, Omlor, & Giese, 2011; Gong, Medioni, & Zhao, 2014; Krüger et al., 2017; Zhou, De la Torre, & Hodgins, 2012). Essentially, a change-point indicates a difference in statistical properties of the data within a sliding window (Aminikhanghahi & Cook, 2017; Fathy, Barnaghi, & Tafazolli, 2018; Liu, Yamada, Collier, & Sugiyama, 2013; Patterson et al., 2016). The sliding window is a free parameter that adjusts time-scale (i.e., granularity). Depending on the method, other free parameters may need to be adjusted. Zameni et al. (2020) described a method that efficiently identifies segmentation boundaries in signals that can be highly dimensional. This method has initialization parameters, but no parameters that can be used to explicitly adjust time-scale or relevance. The cited systems were tested with various types of data. When the test data had been recorded by triaxial accelerometers, the tests aimed to segment activities that take at least a few seconds to complete. However, segments of dancing motion may range from less than a second to more than a few seconds.

Boundaries of Self-Similarity Checkerboard Patterns

The detection of change-points in motion data can be seen as equivalent to novelty detection, which is the identification of abrupt changes in data by a system, without training of the system (Markou & Singh, 2003). Foote (2000) described a method suitable for finding segmentation boundaries in musical audio signals. This method exploits the characteristic checkerboard patterns that can be observed in a self-similarity distance matrix of audio features through time, by correlating a checkerboard kernel along the diagonal of the matrix. This results in a novelty score that indicates the rate of change in the data. The peaks of the

novelty score indicate change-points that correspond to perceived changes in the music. The granularity of the novelty score is adjusted with the width of the kernel and relevant peaks can be selected over a threshold.

Assessment of Effectiveness

To measure the effectiveness of segmentation algorithms, most published studies have relied at least to some extent on classic measures of precision, recall and accuracy, by comparing human-annotated ground truth boundaries annotated by one or more people with computed boundaries. These measures work well for classification problems in which the options are either "match" or "not a match" between a computed boundary and a ground truth boundary. Dreher et al. note that a computed segmentation boundary being only slightly different to the ground truth should be counted as a match. This is usually solved by establishing a window around each ground truth boundary. A computed point is deemed to be a true positive if it lies within that window. This approach was used in the study by Zameni et al., for example. Dreher et al. proposed a method that involves a window weighted with a normal distribution. However, the problem with this approach is that the window's width is fixed while there is no certainty that any given width will correspond to the true probability distribution for the occurrence of a boundary, for all boundaries. It is not possible to generalize the temporal length of the transition from one motion to another. In contrast, the evaluation method used by Gharghabi et al. consists of a score that measures the temporal distance between each computed boundary and the closest boundary in the ground truth. All the distances are added and then divided by the total time. However, this score does not penalize extra or missing computed boundaries, which is problematic as there is no certainty that the number of annotated and computed boundaries will always be the same. Lin et al. (2013) describe another approach for evaluation of results, in which all frames in the ground truth segments are labelled and the number of frames in the computed segments corresponding to the ground truth-labels constitute the measure of similarity. This last method might be appropriate for classification of segments but it might be too restrictive for evaluating only the boundaries. This is because boundaries of short false-positive computed segments (e.g., transitions between motions) will break the continuity of parallel labelling resulting in a very high dissimilarity score. Mendoza (2014), and also Mendoza and Thompson (2017), proposed similarity scores that measure the distance between ground truth and computed boundaries as in the method by Gharghabi et al., but also penalize missing or extra computed boundaries.

The Present Study

The following section describes the implementation of Foote's algorithm for the segmentation of accelerometer data. Then, an experimental assessment is described in which ground truth is used to tune the algorithm's free parameters using a revised version of the similarity measure by Mendoza and Thompson. In contrast to previous studies, the computed results are not assessed by means of a similarity measure but manually by the same annotators who provided the ground truth.

METHODS

Detection of Segmentation Boundaries

This subsection describes the method for finding temporal segmentation boundaries, focusing on its online implementation and its adaptations to work with accelerometer data. A succinct description of the original offline version is provided. For details of the algorithm in general and the offline version, the reader is directed to the original source (Foote, 2000).

The offline version of the algorithm has as input data stored in memory, which has been sampled at regular intervals. This data is represented by the matrix $M \in \mathbb{R}$, so that $M_{1:m} = [F_1, F_2 \dots F_m]^{\mathrm{T}}$. Each frame F at time-index $t \in \{1 \dots m\}$ contains data for each sample. A distance matrix $D \in \mathbb{R}^{m \times m}$ is computed for all data in M. D is a self-similarity matrix. A two-dimension checkerboard kernel is produced by the Kronecker product of checkerboard matrix C and only-ones matrix J of width n as follows:

$$C = \begin{bmatrix} -1 & 1 \\ 1 & -1 \end{bmatrix} \tag{1}$$

$$K = C \otimes J \tag{2}$$

K is then tapered by multiplying it element-wise with a two-dimensional Gaussian (i.e., a normal distribution). Next, K is correlated along the diagonal of D. The result of this correlation is novelty score N, the peaks of which indicate the locations of segmentation boundaries. The peaks can be selected by a threshold θ, discarding peaks of lower values that might be irrelevant. Hence, n and θ are free parameters for granularity and peak relevance, respectively.

The online version of the algorithm consists in M being a stream of data frames $F_t = (f_x^t, f_y^t, f_z^t)$, sampled at regular intervals, containing the three axes of the accelerometer. A window of n frames is stored in a buffer W_{nov} (Figure 1a). For each incoming frame, the last frame in the buffer is removed while the current frame is stacked in the first position, and distance matrix $D \in \mathbb{R}^{n \times n}$ is computed for W_{nov} (Figure 1b). In this study, Euclidean distance was used. Then, the inner product between Gaussian-tapered checkerboard kernel K and D is computed, resulting in a new point in novelty score N (Figure 1c).

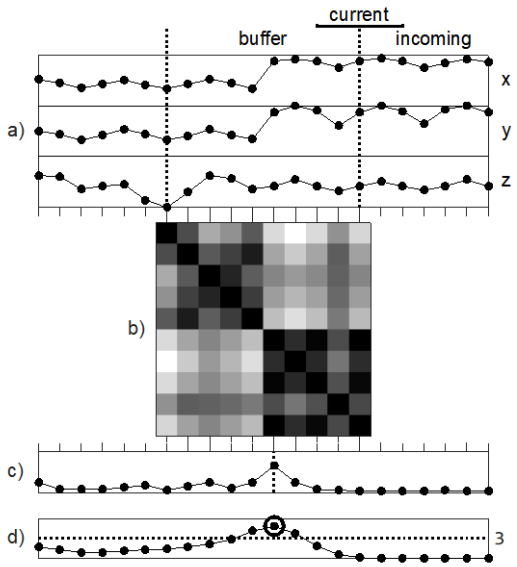

Figure 1. Online detection of temporal segmentation boundaries. Horizontal axes represent time. (a) is triaxial accelerometer data. (b) is self-similarity matrix D of data in the buffer W_{nov}, where lighter shades represent more distance. (c) is novelty score N, where the vertical dotted line indicates the current result. (d) is the smoothed novelty score N', where θ is a threshold and the point in a circle is the selected peak indicating a segmentation boundary. Note that this visualization shows N and N' aligned in time, but in practice there will be a lag due to the low-pass Gaussian filter and the test for a peak.

When tested, Ncontained many irrelevant peaks. Therefore a low-pass filter was applied. The filter used in this study was a one-dimension Gaussian kernel with minima zero and unit area to prevent artefacts at borders and to preserve scale, respectively. This filter is computed upon a second buffer W_{filt} having the size of the one-dimensional Gaussian n_{filt}, resulting in a smooth novelty score N'. Finally, if the current novelty score value is a peak over threshold θ, it is considered a segmentation boundary (Figure 1d). Identification of peaks requires another buffer of only three samples to test a local maximum. Hence, the identification of a novelty peak has lag

$$l = \frac{n+ n_{filt}}{2} + 3 \tag{3}$$

with respect to the current incoming frame.

Since self-similarity matrix D is symmetric, it is necessary to compute only half of it, either the upper or lower triangle, without the diagonal. Also there is no need to compute the whole triangle for each new frame. It is only needed to initialize matrix D with allocation values (e.g., zeros), then compute the distance between the current frame and all the other frames in the buffer. Then, compute the inner product of the upper or lower triangle of D and the corresponding triangle of K. This will output the current novelty value. Then the values within D are shifted, discarding the distances between the oldest frame and the newer ones.

This operation reallocates memory indexes, which takes much less computation time than redundant computation of distance.

The time-scale of the segments may be adjusted dynamically with parameters n and θ. This may be accomplished by fixing the ratio between parameters n_{nov} and n_{filt}, so that parameter n modifies the size of buffers W_{nov} and W_{filt} at the same time. When changing n, a new checkerboard kernel may be computed, or a kernel may be selected from many that might have been previously computed and stored in memory. Because of the operations on D and K, the asymptotical memory complexity is $O(n^2)$ while computing-time complexity is linear. However, in practice n may not grow too much to present a concern, as its size would be limited to the intended granularity and may be reduced by reducing the sampling rate.

Accelerometer Data Collection

Two participants, one female and one male, provided motion data to test the segmentation method. This data was collected at the motion-capture laboratory of the department of Music, Art and Culture Studies at the University of Jyväskylä. These participants are referred to as *dancers* to differentiate them from the participants that provided data for the ground truth and perceptual assessment (see subsection "Ground truth annotation").

In individual sessions, the dancers were asked to "dance with one arm" while holding with the corresponding hand a Nintendo Wii-remote controller. They were asked to move to the music, without displacement of the body, and always facing one corner of the room. While these conditions may not generalize to all dancing scenarios, they provided a clear view of the moving arm to a video camera. Video recordings were later used for manual annotation. The elimination of the random variable of orientation facilitated the annotation task. Also it simplified the analysis, thus making it possible to focus on first solving the segmentation problem in a simple condition before embarking on a more complex scenario. The dancers were told that other than these constraints, they could move as they wanted.

Three musical stimuli were presented through loudspeakers:

1. "Minuet" (Petzold, ca. 1725) MIDI rendition with piano sound, from beginning to end (104 bars, duration 92.5 s.) with no fade-in or fade-out. It has a ternary metre (3/4, or three beats per bar). Both participants declared to know this piece.
2. "Ciguri" (Otondo, 2008) from 56 to 183.7 s. (duration 122.7 s.) with fade-out the last 5 s. This is an electroacoustic piece that has no perceivable beat and therefore no metre. Both participants declared to not know this piece.
3. "Stayin' Alive" (Gibb, Gibb, & Gibb, 1977) from the beginning to 108.5 s. with fade-out the last 2.3 s. It has a binary metre (4/4, or four beats per bar). Both participants declared to know this piece.

The number of performances amounted to six. This was deemed enough for this study as they provided variety: musical genre, metre, familiarity and the gender of the participants. These characteristics would permit to observe to some extent their effect on the test. Furthermore, later these performances were used for the task described in the next section

("Ground truth annotation"). More performances would have extended the annotation task implying the risk of abandonment or fatigue, the latter reducing the reliability of results.

Stimuli were presented in the order listed above and each stimulus was presented twice. During the first presentation, participants were asked to move freely within an area of about $4m^2$, to familiarize themselves with the stimulus. For the second presentation, participants were asked to dance with one arm as described above. Data of the performances were recorded as follows:

- *Accelerometer:* The Nintendo Wii-remote has a triaxial accelerometer, which transmits data in real-time via Bluetooth. This stream was received and recorded by a computer at a rate of 100 Hz, using custom-made software.
- *Video:* A digital video camera recorded video showing the participant's whole body against a white wall. Both participants used their right arm, and were recorded so the image clearly showed the moving arm.
- *Audio:* Digital audio was captured by the microphone of the video camera and by a microphone hanging from the ceiling. The latter was recorded to a digital audio workstation synchronized with the recording of accelerometer data. These signals were subsequently used to synchronize video and accelerometer data.

Ground Truth Annotation

Six participants (3 male, 3 female) were recruited to identify segmentation boundaries in the one-arm-dancing videos. None of them had participated in the data collection described in the previous section. Their ages ranged from 26 to 34 years, with a median age of 27. All were non-Finnish international students at the University of Jyväskylä. All had completed at least an introductory course in music psychology, covering an introduction to perception and segmentation. These participants are referred to as *annotators*, to differentiate them from the *dancers* who performed the one-arm dance (see subsection "Accelerometer data collection").

Each annotator, in an individual session, was asked to watch the videos and identify segmentation boundaries in two conditions. In the first condition, the videos with audio were presented by a computer running custom-made software. The annotators were instructed to press a key when a boundary was identified, in real time. The time of the key relative to the video was recorded by the computer. They had only one chance to perform the task. It was thought that the music in the video may influence the responses as auditory cues, such as pitch or rhythm, and could be used to judge the existence of a boundary. For the second condition, the videos without audio were presented by the computer running a digital audio editor software. In this condition, participants could freely play the video, pause, scroll forward and backwards, place markers and adjust the location of the markers until they were satisfied. In this condition, the annotators did not have a limit of time for the task and the annotation was based solely on visual information.

The following were the instructions to the annotators, common for both conditions:

"You will be presented with six videos, each lasting around two minutes. Each video shows a person 'dancing' with an arm. When doing this, the person does distinct patterns with the arm. A pattern is composed by one distinct movement or several repetitions of the

same movement. When the video is playing press the space bar to indicate a change in pattern. Focus in the movement of the arm holding the white device (it is a sensor).”

The two annotation conditions represented different approaches for perceived segmentation. To assess their suitability, the annotators were interviewed after completing the tasks. They were asked to verbally express what they considered to be difficult or easy about the tasks. All participants mentioned that, in the real-time annotation task, their responses might have been influenced by the music and they were less precise than in the non-real-time condition. The reasons mentioned for this included that in the real-time condition the responses might have been anticipated as an effect of the music. Also, it was mentioned that, in the real-time task, it was more difficult to press the button exactly at the intended time, thus preventing a response to be recorded accurately or in some cases at all. All participants expressed that the non-real time condition allowed for more precise responses, as they could take time to revise them. Because of this, the data relating to real-time audiovisual annotation was deemed inappropriate for use as a ground truth. Thus, non-real-time visual annotation was chosen as ground truth for perceived segmentation boundaries.

Optimization using similarity based on distance and rate of paired elements

A grid search was performed to maximize the similarity between annotated (ground truth) and computed segmentation boundaries, by modification of parameters *n* and θ. This search was performed independently for each accelerometer recording and their corresponding annotations, mimicking the adjustment that might be achieved manually by an end-user or automatically by a machine-learning procedure. Similarity was evaluated by distance and penalization of extra or missing boundaries, improving previous work (Mendoza, 2014; Mendoza & Thompson, 2017).

Consider vectors a and b containing the time indexes of annotated and computed segmentation boundaries, respectively. L is the length, in samples, of the corresponding recorded data, from the start to the end of the musical stimulus. n_a and n_b are the number of boundaries, or length, of a and b respectively. In any case $n_a \geq n_b$ or vice-versa. Each element in a is paired to the closest element in b, so that a' and b' are vectors containing only the paired elements and have equal lengths n_p (equivalent to the shortest between n_a and n_b). Then, the following measures are computed:

Closeness:

$$c = 1 - \frac{1}{L}\sum_{i=1}^{n_p}|a'_i - b'_i| \quad (4)$$

Rate of paired elements:

$$p = \frac{2n_p}{n_a + n_b} \quad (5)$$

Similarity:

$$S = c \cdot p\ , 0 \geq S \geq 1 \quad (6)$$

The distance between paired boundaries is the absolute time difference, as shown in equation 4. Note that two boundaries of either sequence (a or b) may be paired with a single boundary in the other sequence if their distances are equal. Also, if n_a and n_b are not equal and there are no equidistant boundaries to compensate for that inequality, then some boundaries will not be paired and this will be penalized by the rate of paired elements (equation 5). A Monte Carlo simulation was computed with pseudo-random a and b, for $L = 1000$, with n_a and n_b in the range $\{1 \ldots L-1\}$, and 10^4 iterations. The distribution for the resulting S values has an upper p-value of 0.05 at $S = 0.66$.

Perceptual Assessment

The perceptual assessment was made by the same annotators that provided the ground truths. For each annotator, the annotated and computed boundaries with highest similarity were selected. This means that the assessment is for the 'best case scenario'. For each of these sequences of boundaries a video was produced embedding a scrolling timeline with consecutive numbers for boundaries into the corresponding video that was annotated (Figure 2).

Three videos were produced for each annotator. One had markers for their original annotation, to measure the extent of agreement they would have with the annotation they had previously made. A second video had markers for the computed boundaries. A third video had a confounding sequence of boundaries produced by placing a marker in the middle of the segments bounded by the average point for each pair of paired annotated and computed boundaries. The videos with confounding boundaries were intended to reduce the chance of annotators realizing that one of the sequences was their own annotation, and the responses to those videos were not analyzed.

Figure 2. Example frame of a video shown to an annotator for perceptual assessment. The same video without the numbered markers had been used for annotation.

The videos contained no audio, as the annotations used in the computation of boundaries corresponded to video without audio. Each video was embedded in a webpage and had on-screen controls that could be activated with a pointing device (e.g., mouse, trackpad) to play, stop, scroll forward and backwards. The pages were presented in random order by an automatic system that also recorded responses. Each page consisted of instructions, the video and a list of numbered items, one for each marker. Each item in the list had two buttons that could be selected by clicking on them. One button was to answer "yes, there is a change in pattern" and was recorded as a *confirmed boundary*. The other button was to answer "no, there is no change in pattern" and was recorded as a *rejected boundary*. This assessment is used in replacement of the paradigm used in previous studies that considered a computed boundary to be correct if it is within a window around a ground truth boundary. It has the advantage of not needing to specify a fixed window.

The definition of the task was identical to the one given for the annotation task. One distinct questionnaire was produced for each annotator with the corresponding videos. This questionnaire did not reveal how the segmentation sequences were produced. After completing each page all responses were recorded and options were shown to immediately continue to the next page or to continue later. The annotators were asked to complete the questionnaire in their own space and time, using their own computers and to take as much time as they needed.

The decision to assess the best-case-scenario boundaries was made after testing the questionnaire. This test was done with different participants who would take up to 50 minutes to complete a questionnaire with three videos. It was decided that the questionnaire should not exceed three videos, to prevent fatigue and abandonment.

The data obtained from the questionnaires was processed to obtain the following relevance measures:

$$Precision(computed) = \frac{n_{cb}}{n_b} \tag{7}$$

$$Recall(computed) = \frac{n_{cb}}{n_{cb}+n_{ca}-n_p} \tag{8}$$

$$Precision(annotated) = \frac{n_{ca}}{n_a} \tag{9}$$

where n_{cb} is the number of confirmed computed boundaries (true positives), n_b is the number of computed boundaries (true and false positives), n_{ca} is the number of confirmed annotated boundaries, n_p is paired annotated and computed ($n_{ca} - n_p$ is false negatives), and n_a is the number of annotated boundaries (true and false positives). $Precision(annotated)$ may be considered as an indication of the assessment's reliability. It is not possible to obtain $Recall(annotated)$ as false negatives would require the possibility of adding new boundaries, which was not part of the assessment task.

RESULTS AND DISCUSSION

Computation of the grid search was performed with the recorded accelerometer data downsampled to 25 Hz. The standard deviation σ for the two-dimensional Gaussian that tapers *K* and the one-dimensional Gaussian smoothing filter for N' were set to $\sigma = n/5$. The length of the one-dimensional Gaussian was set to *n*; that is, to the width of K and D. The standard deviation of both Gaussians was searched within $\sigma = \{0.5,0.6,\ldots,2\}$ seconds. Since recorded accelerometer data was used, computation was performed in non-real-time. Therefore, the filtered novelty score was rescaled to $0 \geq N \geq 1$ and the threshold for peak selection was searched within $\theta = \{0,0.1,\ldots,0.5\}$. For real-time computation, these values would yield a lag time of l = {0.22, 0.24, ..., 0.52} seconds. Note that lag time does not consider computation time, which depends on the specific computing device used.

The highest lag time among the results is 0.5s, for the segmentation corresponding to Annotator 2, of Dancer 1, to "Minuet". The median lag time was 0.35s. Considering this time scale, this system is not suitable for any practical application that requires immediate perceptual real-time response (i.e., up to about 10 to 50 milliseconds). However, this lag time is suitable for applications in which the occurrence of a segmentation boundary is not to be acted upon immediately. For example, this delayed response may be mapped to a procedure that changes the stimulus music in such a way that it prompts the dancer to change the motion pattern, thus creating a feedback loop. Another use of this delayed response is to record the segments' times, then compute statistics (e.g., mean, standard deviation) and use those for a larger time-scale control of music, lights or other actionable medium. Furthermore, the segmentation result may be used to produce a near-real-time visual or sonic display that may be useful in clinical applications and research in biomechanics, for example.

Tables 1 and 2, respectively, show values for maximum distance d and similarity (S) obtained in the grid search, where $d = |a' - b'|$. The distance is expressed in seconds. The minimum similarity value ($S = 0.56$) has a p-value of 0.39, while the minimum mean similarity value ($S = 0.62$) has a p-value of 0.17. These minimum values represent the worst performance of the automatic segmentation. The greatest mean S values were found for the musical stimuli "Minuet" and "Stayin' Alive", which both have a clear beat and were familiar to the dancers. Conversely, similarity is lower for "Ciguri", which is a piece that has no clear beat and was not familiar to the dancers. This suggests that the effectiveness of the method may be directly related to both or either of these conditions: the presence of a clear beat, and the familiarity the dancers might have with the musical stimulus. Also the table shows that most maxima d seem too large to indicate corresponding paired boundaries. Although this may be considered a limitation of the method, it is still possible that the highly distant computed boundaries are confirmed in the perceptual assessment.

Table 1. Maximum Distance (d) in seconds, between Annotated and Computed Boundaries.

	Dancer 1			Dancer 2		
Annotator	Minuet	Ciguri	Stayin' Alive	Minuet	Ciguri	Stayin' Alive
1	3.80	2.52	2.62	2.33	6.07	2.11
2	4.11	3.59	1.69	5.67	6.74	2.22
3	4.53	7.87	1.96	3.60	5.31	2.84
4	4.44	3.10	3.74	1.15	5.78	3.29
5	3.82	6.31	2.79	2.13	2.27	0.73
6	1.59	2.86	2.72	2.47	1.90	1.56
mean	3.71	4.38	2.52	2.89	4.68	2.13

Table 2. Similarity (S) between Annotated and Computed Boundaries.

	Dancer 1			Dancer 2		
Annotator	Minuet	Ciguri	Stayin' Alive	Minuet	Ciguri	Stayin' Alive
1	0.64	0.66*	0.74*	0.71*	0.75*	0.83*
2	0.76*	0.63	0.68*	0.82*	0.63	0.80*
3	0.71*	0.60	0.68*	0.71*	0.68*	0.91*
4	0.61	0.57	0.74*	0.82*	0.67*	0.74*
5	0.66*	0.68*	0.73*	0.64	0.63	0.71*
6	0.56	0.60	0.70*	0.64	0.61	0.74*
mean	0.66*	0.62	0.71*	0.72*	0.66*	0.79*

* $p \leq 0.05$ (not adjusted for multiple comparisons)

Table 3 contains relevance values for the case of maximum similarity for each annotator. The corresponding sequences of annotated and computed boundaries are visualized in Figure 3. The fifth and sixth boundaries of Annotation 2 seem to be too far for any of them to correspond to the fifth computed boundary. However, this boundary was confirmed in the perceptual assessment. It is not possible to conclude whether this boundary corresponds to any of the annotated boundaries, or if it is a new boundary that was unseen at the annotation task (i.e., serendipity effect) or if it was a mistake made by the annotator in the assessment task.

Table 3. Perceptual Assessment of Annotated and Computed Segmentation with Highest Similarity (S) for each Annotator.

Annotator	**Stimulus**	**Dancer**	$\boldsymbol{S}$	$\boldsymbol{Precision\ (computed)}$	$\boldsymbol{Recall\ (computed)}$	$\boldsymbol{Precision\ (annotated)}$
1	Stayin' Alive	2	0.83	0.75	0.82	1
2	Minuet	2	0.82	0.86	0.86	0.75
3	Stayin' Alive	2	0.91	0.89	1	0.67
4	Minuet	2	0.82	0.71	1	0.71
5	Stayin' Alive	1	0.73	0.71	0.88	0.95
6	Stayin' Alive	2	0.74	0.80	0.92	0.86
mean			0.81	0.79	0.91	0.82

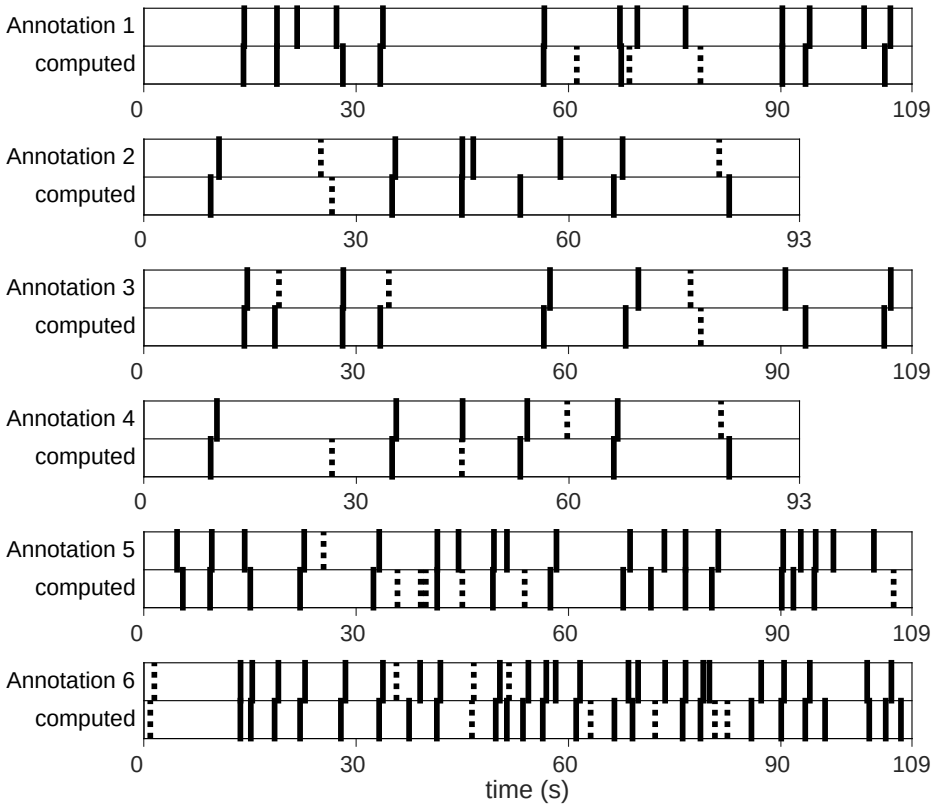

Figure 3. Annotated and closest computed segmentation boundaries for each annotator, corresponding to Table 3. Full lines indicate confirmed and dotted lines indicate rejected.

Another problem is that most annotators rejected boundaries that they had previously annotated, as shown by measure $Precision(annotated)$. While these values are fairly high, some assessment responses look counter-intuitive. For instance, the third boundary of Annotation 4 is evidently close enough to its computed counterpart to be considered an exact match. However, the computed boundary was rejected as shown by the dotted line. Another example that may cast doubt on the perceptual task is the second and fourth boundaries of Annotation 3. These were rejected but their computed counterparts, even being noticeably very near, were confirmed. These odd assessment responses are not the norm, but they raise questions about the reliability of the perceptual tasks.

The two aforementioned assessment problems may be solved by a revised questionnaire including a task that shows both annotated and computed boundaries in the same time line, thus making evident to the annotator the distance between them. In addition, the task would require the annotator to explicitly indicate the corresponding annotated boundary for each computed boundary and vice-versa, if such correspondence exists. Despite the drawbacks of the segmentation and assessment methods, the best-case scenario reveals very high Precision and Recall values. This is relevant as the best-case scenario is akin to the best possible re-tuning that a user could make in a practical application scenario.

A further limitation of this study is that the annotation and assessment tasks were done at different times. This explain the odd responses mentioned above. A possible solution would be to integrate annotation, automatic segmentation, optimization, and assessment, into one procedure.

CONCLUSIONS

This article has presented an adaptation, testing and perceptual assessment of a method to compute segmentation boundaries in accelerometer data. The method is based on an algorithm widely used for segmentation of digital audio (Foote, 2000). Experimental testing of the adapted and extended algorithm used accelerometer data of subjects moving their arm to music, as a simplistic form of dance, from which segmentation boundaries were computed. The fine tuning of the algorithm's parameters was based on annotators' responses, using a novel measure of distance of paired elements between computed and annotated boundaries, combined with penalization for missing or extra boundaries. Perceptual assessment, consisting of rejection or confirmation of computed boundaries, resulted in fairly high values for measures of relevance *Precision* and *Recall*. The segmentation procedure requires a context-dependent minimum time to produce a response, which in this study was maximum about half a second. This is suitable for systems that do not require an immediate response.

Future work on the perceptual assessment of segmentation boundaries should include a task to pair computed and annotated boundaries, in combination with the task to reject or confirm boundaries. It would also be useful to evaluate more and different input data modalities for computing segmentation, as well as manually or automatically learned features that might improve effectiveness. Furthermore, after the segmentation and assessment methods presented in this article are improved as mentioned, they should be incrementally tested on more complex motion and more realistic conditions. Possible next steps might be to attempt segmentation of dancing motion using both arms, legs, the full body, allow free displacement, different musical stimuli and so forth.

IMPLICATIONS FOR RESEARCH AND APPLICATION

This study has developed and tested a system to produce near-real-time segmentation sequences of accelerometer data. This system may be useful for proposing segmentation to a final user, making the process faster than manually. For example, the system could produce several sequences at different granularity levels, out of which the user selects the most appropriate. Likewise, a matrix of multigranular segmentation sequences may be used without any further screening by the user. As such, the system may see a number of practical applications, for example the inspection of data (e.g., identification of daily activity events in data recorded by a wearable accelerometer) or mapping the segmentation results to actionable processes (e.g., gestural control of music, lights, etc.). An important contribution of this study is the formulation of a novel non-parametric similarity measure based on distance and rate of paired elements. Although the measure was developed to assess similarity of segmentation sequences, it may be used to assess the similarity between any pair of sequences of ordered numbers.

REFERENCES

Aminikhanghahi, S., & Cook, D. J. (2017). A survey of methods for time series change point detection. *Knowledge and information systems, 51*(2), 339-367. https://doi.org/10.1007/s10115-016-0987-z

Bernard, J., Dobermann, E., Vögele, A., Krüger, B., Kohlhammer, J., & Fellner, D. (2017). Visual-interactive semi-supervised labeling of human motion capture data. *Electronic Imaging, 2017*(1), 34-45. https://doi.org/10.2352/ISSN.2470-1173.2017.1.VDA-387

Bläsing, B.E. (2015). Segmentation of dance movement: effects of expertise, visual familiarity, motor experience and music. *Frontiers in psychology 5*, 1500. https://doi.org/10.3389/fpsyg.2014.01500

Cornacchia, M., Ozcan, K., Zheng, Y., & Velipasalar, S. (2017). A survey on activity detection and classi cation using wearable sensors. *IEEE Sensors Journal 17*(2), 386–403. http://doi.org/10.1109/JSEN.2016.2628346

Dreher, C. R., Kulp, N., Mandery, C., Wächter, M., & Asfour, T. (2017). A framework for evaluating motion segmentation algorithms. In *2017 IEEE-RAS 17th International Conference on Humanoid Robotics (Humanoids)* (pp. 83-90). IEEE. https://doi.org/10.1109/HUMANOIDS.2017.8239541

Endres, D., Christensen, A., Omlor, L., & Giese, M.A. (2011). Emulating human observers with bayesian binning: Segmentation of action streams. *ACM Transactions on Applied Perception (TAP), 8*(3), 1-12. https://doi.org/10.1145/2010325.2010326

Fathy, Y., Barnaghi, P., & Tafazolli, R. (2018). An Online Adaptive Algorithm for Change Detection in Streaming Sensory Data. *IEEE Systems Journal*, *13*(3), 2688-2699. https://doi.org/10.1109/JSYST.2018.2876461

Foote, J. (2000). Automatic audio segmentation using a measure of audio novelty. In *2000 ieee international conference on multimedia and expo. ICME2000. Proceedings.* (Vol. 1, pp. 452-455). IEEE. https://doi.org/10.1109/ICME.2000.869637

Foote, J. T., & Cooper, M. L. (2003). Media segmentation using self-similarity decomposition. In *Storage and Retrieval for Media Databases 2003* (Vol. 5021, pp. 167-175). International Society for Optics and Photonics. https://doi.org/10.1117/12.476302

Gharghabi, S., Yeh, C.C.M., Ding, Y., Ding, W., Hibbing, P., LaMunion, S., Kaplan, A., Crouter, S.E., & Keogh, E. (2019). Domain agnostic online semantic segmentation for multi-dimensional time series. *Data Mining and Knowledge Discovery, 33*(1), 96–130. https://doi.org/10.1007/s10618-018-0589-3

Gibb, B., Gibb, R., & Gibb, M. (1977). Stayin' alive. In *Saturday Night Fever, The Original Motion Picture Soundtrack*. Germany: RSO.

Gong, D., Medioni, G., & Zhao, X. (2014). Structured time series analysis for human action segmentation and recognition. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 36*(7), 1414–1427. https://doi.org/10.1109/TPAMI.2013.244

Kahol, K., Tripathi, P., & Panchanathan, S. (2004). Automated gesture segmentation from dance sequences. In *Sixth IEEE International Conference on Automatic Face and Gesture Recognition, 2004. Proceedings.* (pp. 883–888). IEEE. https://doi.org/10.1109/AFGR.2004.1301645

Krüger, B., Vögele, A., Willig, T., Yao, A., Klein, R., & Weber, A. (2016). Efficient unsupervised temporal segmentation of motion data. *IEEE Transactions on Multimedia, 19*(4), 797-812. https://doi.org/10.1109/TMM.2016.2635030

Krüger, V., Kragic, D., Ude, A., & Geib, C. (2007). The meaning of action: A review on action recognition and mapping. *Advanced robotics, 21*(13), 1473-1501. https://doi.org/10.1109/TMM.2016.2635030

Lin, J.F.S., Karg, M., & Kulić, D. (2016). Movement primitive segmentation for human motion modeling: A framework for analysis. I*EEE Transactions on Human-Machine Systems 46*(3), 325–339. https://doi.org/10.1109/THMS.2015.2493536

Liu, S., Yamada, M., Collier, N., & Sugiyama, M. (2013). Change-point detection in time-series data by relative density-ratio estimation. *Neural Networks, 43*, 72-83. https://doi.org/10.1016/j.neunet.2013.01.012

Markou, M., & Singh, S. (2003). Novelty detection: a review—part 1: statistical approaches. *Signal processing*, *83*(12), 2481-2497. https://doi.org/10.1016/j.sigpro.2003.07.018

Mendoza, J.I. (2014). Self-report measurement of segmentation, mimesis and perceived emotions in acousmatic electroacoustic music. Master's thesis. University of Jyväskylä. http://urn.fi/URN:NBN:fi:jyu-201406192112

Mendoza, J. I., & Thompson, M. (2017). Modelling Perceived Segmentation of Bodily Gestures Induced by Music. In *ESCOM 2017: Conference proceedings of the 25th Anniversary Edition of the European Society for the Cognitive Sciences of Music (ESCOM)*. Ghent University. http://urn.fi/URN:NBN:fi:jyu-201711024121

Otondo, F. (2008). Ciguri. In *Tutuguri*. Sargasso.

Patterson, T., Khan, N., McClean, S., Nugent, C., Zhang, S., Cleland, I., & Ni, Q. (2016). Sensor-based change detection for timely solicitation of user engagement. *IEEE Transactions on Mobile Computing*, *16*(10), 2889-2900. https://doi.org/10.1109/TMC.2016.2640959

Petzold, C. (ca. 1725). Minuet in G major. *The Anna Magdalena Bach Notebook*, Anh. 114.

Rodrigues, J., Probst, P., & Gamboa, H. (2021). TSSummarize: A Visual Strategy to Summarize Biosignals. In *2021 Seventh International conference on Bio Signals, Images, and Instrumentation (ICBSII)* (pp. 1-6). IEEE. https://doi.org/10.1109/ICBSII51839.2021.9445154

Schätti, G. (2007). Real-Time Audio Feature Analysis for Decklight3. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.85.7916&rep=rep1&type=pdf

Tardieu, D., Chessini, R., Dubois, J., Dupont, S., Hidot, S., Mazzarino, B., ... & Visentin, A. (2009). Video Navigation Tool: Application to browsing a database of dancers' performances. *on Multimodal Interfaces eNTERFACE'09*, 35. http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=0249E27EDBD8D12E8FF58DE4F9ABC18A?doi=10.1.1.159.3151&rep=rep1&type=pdf

Zacks, J. M., Kumar, S., Abrams, R. A., & Mehta, R. (2009). Using movement and intentions to understand human activity. *Cognition*, *112*(2), 201-216. https://doi.org/10.1016/j.cognition.2009.03.007

Zameni, M., Sadri, A., Ghafoori, Z., Moshtaghi, M., Salim, F. D., Leckie, C., & Ramamohanarao, K. (2020). Unsupervised online change point detection in high-dimensional time series. *Knowledge and Information Systems*, *62*(2), 719-750. https://doi.org/10.1007/s10115-019-01366-x

Zhou, F., De la Torre, F., & Hodgins, J. K. (2012). Hierarchical aligned cluster analysis for temporal clustering of human motion. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *35*(3), 582-596. https://doi.org/10.1109/TPAMI.2012.137

Authors' Note

This study was partially funded by the Finnish Foundation for Technology Promotion (Tekniikan edistämissäätiö). All correspondence should be addressed to Juan Ignacio Mendoza, at the University of Jyväskylä, email: juigmend@student.jyu.fi

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

Human TECHNOLOGY

ISSN: 1795-6889

https://ht.csr-pub.eu Volume 18(3), December 2022, 267-296

IS THE SHOPPING LIST A GUARANTEE FOR RATIONAL CONSUMER BEHAVIOUR?

Kamila Słupińska
University of Szczecin
Poland

Katarzyna Włodarczyk
University of Szczecin
Poland

Mariusz Borawski
University of Szczecin
Poland

Patryk Wlekły
University of Szczecin
Poland

Abstract: *Consumers may undertake various steps in order to increase the rationality of their choices. One of the options involves drawing up a shopping list. The study presents an innovative method of analysing consumer behaviour during shopping. Modern technologies were used to set up a virtual environment within which a store was created. A combination of methods was employed to assess the subjective opinions expressed during in-depth interviews. Another step focused on analysing the internal stimuli of the research subjects with the use of neuroscientific tools to evaluate the behaviour of the research participants. The aim of the study was to verify the impact of a shopping list on consumer rationality. The research results presented constitute a part of a broader research project, within the scope of which research method triangulations enabled an in-depth analysis of conscious and unconscious aspects of the subjects' behaviour (Borawski et al. 2021).*

Keywords: *EEG, VR, price sensitivity, consumer behaviour, consumer rationality*.

DOI: https://doi.org/10.14254/1795-6889.2022.18-3.5

INTRODUCTION

Global economic and social development results in changes in the standards of living and in the arrival of new goods and services on the market. Accordingly, the models of consumer behaviour and decisions made by consumers are subject to changes as well. Reference books on consumer behaviour stipulate that the principle of rationality lies at the foundation of actions taken by consumers (Hall, 1990; Hartman, Doane, & Woo, 1991; Peck, 2012). However, this principle is not always put into practice (Galbraith, 1938; Jacoby, 2000; Wang, Shen, & Gao, 2018). The objective of the paper is to assess consumers' rationality / irrationality, depending on whether or not they have drawn up a shopping list. The article features theoretical deliberations which are based on the existing relevant reference books and supported by the research. Methods and research tools used in the study made it possible to analyse both conscious and unconscious aspects of consumer behaviour, which allowed for a wider look at the subject matter under analysis. The assumptions were verified with the use of an interview (dyads and triads) and an experiment carried out in virtual reality, for which neuroscientific tools, such as EEG were employed. The research hypothesis was worded as follows: 'Having a list influences shopping behaviour on site'. There were also three supporting hypotheses: (h1) the shopping route of individuals with a shopping list is shorter in comparison to those without the list; (h2) individuals with a shopping list buy products more quickly; (h3) individuals doing shopping without a list demonstrate more positive emotions than the ones with the list. Consumers and their behaviour have been studied for many years (Ferber, 1977; Jacoby, Szybillo, & Berning, 1976; Triandis, 1979). Contemporary research of consumer behaviour demonstrates the complexity of the subject and incorporates multiple academic fields, such as, inter alia, economics, sociology, psychology, or medicine (Ferber, 1977; Szwacka-Mokrzycka, 2015; Xiao, Ford, & Kim, 2011). The studies provide information not only on why customers buy, but also on the course of a decision-making process, as well as the internal and external factors that may affect individual stages of this process (Biliciler et al., 2022; Concari et al., 2020; Włodarczyk, 2013).

On account of an interdisciplinary approach to the research, contemporary definitions of consumer behaviour encompass various aspects of consumer activity on the market, be it: economic (e.g. the purchase process), social (e.g. individual's behaviour in a group) and psychological (e.g. achievement of satisfaction) (Engel, Miniard, & Blackwell, 2006; Enis, 1977; Kotler & Keller, 2011; Kumar, 2010; Schiffman, Kanuk, & Hansen, 2008). Special attention to the issues of consumer behaviour arose due to the pandemic restrictions and their impact on attitudes toward shopping (Holotová et al., 2020; Huszka et al., 2022) which caused appropriate business responses in form of the strengthening links with the consumers (Mishchuk et al., 2022). One such interdisciplinary definition was proposed by M.R. Solomon (1995, 2006), who recognized that consumer behaviour entailed the process of choice, purchase, use, acceptance or rejection of products, services and experiences in order to satisfy the needs and wants by an individual or a group. A similarly broad approach to the subject was demonstrated by G. Antonides and W.F. Raaij (2002). According to their opinion, consumer behaviour comprises mental and physical activities along with motivations and causes; it refers both to group and individual behaviour; it concerns the cycle of consumption, i.e.: orientation, buying, using, keeping and disposing of a product; it involves

goods and services purchased in the market sector and public sector, or the ones manufactured within the scope of a household operation; it enables an individual or a group to function in such a way so as to ensure satisfaction and to achieve prosperity through individual and social effects of such behaviour. One of the most exhaustive definitions was proposed by M. de Mooij'a (2021), according to which consumer behaviour is treated as a process of choice, purchase, use, management of goods, services and experiences in order to achieve satisfactory fulfilment of wants and needs. In this definition, the focus is on the elements of contemporary studies of consumer behaviour, with an emphasis on the attributes of an individual and of a decision-making process (the element of psychology and sociology), management and a possibility of choice (the element of management and economics) as well as values and culture (the element of cultural studies).

- Consumers' needs lie at the foundation of the decisions made by the consumers. Consumer needs play an important role in the analysis of consumer behaviour on the market. Typically, they are understood as a demand for specific goods and services. One of the definitions of a consumer need has been presented by J. O'Shaughnessy (1994, 2013). According to the author, a consumer's need is an inclination to use or possess a product, but also an inclination towards a certain form of behaviour. Simultaneously, the author has isolated two main types of needs when discussing consumer needs, namely, desire and a requirement. The former type (the desire) refers to the need that has not been satisfied; the latter type (the requirement) is understood as a demand or a universal requirement for a given product or service. The views on consumer needs were supplemented by J. O'Shaughnessy (1994, 2013) who added an assumption that consumer needs also included desire for values in use, arising from the achieved economic and cultural mankind's development

Every consumer tries to make rational choices, is guided by their own hierarchy of needs (Maslow, 1943; Maslow, 1954; Maslow, 1962; Maslow, 1970). The hierarchical structure of needs and values of an individual is the result of such individual's psyche and personality. However, such an individual hierarchical system of needs is not constant and it evolves throughout the person's lifetime (Wahba & Bridwell, 1976). It depends on biological, social, economic and psychological circumstances (Kenrick, Griskevicius, Neuberg, & Schaller, 2010). It is believed in the literature that each consumer, based on their own hierarchy of needs, makes rational choices and purchases, and in this way they shape their rational consumption structure (Tyszka & Zaleśkiewicz, 2001; Matysik-Pejas & Szafrańska, 2011; Zalega, 2012).

Economic psychology, which originated from the concept of psychological behaviour developed by G. Katona as early as in the 1950s (Katona, 1953), has a major impact on the contemporary analysis of consumers' rational behaviour. According to economic psychology, consumer behaviour had a rational character, i.e. it could be predicted and subject to influence, but it did not depend exclusively on prices and income. It was also dependent on the consumer's perception of economic reality, their expectations and attitudes (Markin, 1979; Krasiński, Piasny, & Szulce, 1984; Drakopoulos, 1989; Samson & Voyer, 2012).

The fundamental objective of a rational consumer seems to be maximization of usefulness (Green & Srivastava, 1986; Molina, 1996; Kahneman & Thaler, 2006; Li & Hsee, 2021). The first factor forcing consumers to think when taking the final and rational purchase

decision is a need, which consumers find to be the source of dissatisfaction and deficiency, and which at the same time arises from their biological, psychological and social characteristics (Bayton, 1958; Seeley, 1992; Griskevicius & Kenrick, 2013). Becoming aware of the reason for a given situation brings about the need to assess the market, obtain information and plan the purchase of a product or a service, the purpose of which is to change the state of dissatisfaction of the decision-making individual (Dima, Man, & Kot, 2010; Peluso, 2011). Rational consumer activities require making certain calculations (Boudon, 2003; D. P. Green & Fox, 2007; Runje et al., 2019; Nickerson, 2021). Additionally, all consumer decisions are dependent upon multiple factors, such as, for instance, economic factors, i.e.: income, prices, savings, credits, influence of marketing instruments, goods availability, as well as non-economic factors, i.e.: age, gender, shopping time, urgency of a need, emotions, habits, planning, and many more (Mowen, 1987; Engel et al., 1997; Lambkin et al., 2001; Włodarczyk, 2013; Schiffman & Wisenblit, 2015; Zhao et al., 2021).

Rationality is not a consistently defined concept (Kahneman, 1994; Chase, Hertwig, & Gigerenzer, 1998; Bazerman & Messick, 2001; Lindenberg, 2001; Zaleśkiewicz, 2015; Bassey, Okoi, Bassey, & Wirawan, 2022). A. Kacelnik (Kacelnik, 2006) believes that recognizing a certain form of behaviour as being rational depends on which definition we refer to. In "The Dictionary of Modern Thought" (Bullock, Stallybrass, Trombley, Eadie, & Adamiec, 1999), rationality is defined as a type of behaviour that satisfies two conditions: consistency and accomplishment of goals, but it is consistency that is meant to allow an individual to accomplish an intended goal. Another definition of rationality can be found in Blackburn's (Blackburn, 2004) "The Oxford Dictionary of Philosophy", in which rationality means sense, suitability, compliance with the goal of the truth and the good. An interesting definition of rationality is also presented by a psychologist, D. Over (Over, 2004), who equates rational activity with people fulfilling specific cognitive standards. At the same time, he deliberates and points out to two divisions of rationality. The first division concerns rationality of beliefs and the rationality of action, which do not always go hand in hand. The second division, a very similar one, points out to theoretical and practical rationality. In the case of the definitions originating from psychology and philosophy, rationality is treated as a process of thinking and decision-making (Zaleśkiewicz, 2015). From the standpoint of economic studies, Neuman and Morgenstern's model (Von Neumann & Morgenstern, 1947) concerning the theory of expected usability can be indicated as one of the fundamental models of rational activity. The model assumes that an individual acting under the conditions of specific risk behaves as if they had their own function of usability defined by available alternatives, and in the face of the risk, when they need to make a decision, they do so in such a way so as to maximise their expectations (Baumol, 1951; Rabin, 2000). With time, alternative models of rationality emerged in economic studies (Allais, 1953; Kahneman & Tversky, 1979). On the one hand, rationality is discussed by using the terms of maximisation/optimisation of benefits/usability/satisfaction that arise from the decision made. This approach to rational activity was presented , inter alia, by Wilkinson & Klaes, 2018; Dudziak, 2013; Zalega, 2014; Arrow, 1982, 1986, 1990; Becker, 1962, 1976; However, other scientists believe that rationality is not always tantamount to maximisation and they point out that a pre-condition for rationality is a satisfactory choice (which does not need to be maximum) – (Leibenstein, 1979a, 1979b, 1988), (Simon, 1976, 1978, 1995).

Undoubtedly, an important element of rationality in the consumer decision-making process is thoughtful product choices. A shopping list used by the consumer while at store and while making final shopping choices may contribute to the accuracy of the final decision being made. Previous studies analysing shopping lists used by the consumers and their impact on consumer behaviour comprised various aspects, such as list compilation, list contents, assistance in memorising shopping items, factors determining the compilation of the final version of the shopping list, the effectiveness of having a list vis-à-vis actually purchased items, developing an external memory, or doing planned and unplanned shopping (Spiggle, 1987; Thomas & Garland, 1993; Freyd & Gleaves, 1996; Block & Morwitz, 1999; Hand, Dall'Olmo Riley, Harris, Singh, & Rettie, 2009; Ghosh & Gilboa, 2014; Harsha Jayawilal & Premeratne, 2017; Martínez-Ruiz, Blázquez-Resino, & Pino, 2017; Ahmed & Ting, 2019; Morrissette & Lusk, 2022). In particular, with regard to the issues raised in this study, planned and unplanned purchases should be treated, because these consumer actions can be combined both with the issues of having a shopping list and the rationality of choices made (Abratt & Goodey, 1990; Hunt & Lambe, 2000; Sohn & Ko, 2021). During shopping in the market, one of the elements refers to the route the shopper follows. It speaks directly to how the shopper moved and can be related not only to the products he or she wanted to buy, but also to those he or she bought on impulse. One of the leading researchers studying this issue, S. Hui and J.Inman, made an attempt to answer this question (Hui, Bradlow, & Fader, 2009; Hui, Inman, Huang, & Suher, 2013). Their study was to compare consumer behaviour in a real shop (not created in VR). They tried to answer the question of how the route through the shop determined the products that would be in the customer's shopping basket. They point out that the route in the real shop depends on many factors - including the shopping list held. Furthermore, the analysis of behaviour through product routes alone is incomplete without the analysis of physiological signals or emotions. (Hui et al., 2009, 2013).

Compared to the study by S. Hui et al., it is possible to point out an important advantage of conducting research using the VR environment, which is its repeatability (Hui et al., 2009, 2013). This means that by using ready software, we obtain constant repeatability of each survey, where we eliminate any factors that may affect the course of the survey. Using, for example, appropriate modelling of customer behaviour in a shop, we can obtain full repeatability of their behaviour or introduce their variability if the research scenario so requires. The VR environment allows for an easy and simple way to change products in the virtual shop, add new prices or set promotions without the need for costly and time-consuming changes to physical products. Furthermore, it allows any configuration of the shop, including shelves and the position of products on them. In addition, we have removed all well-known brands from our shop in order to minimise the phenomenon of buying products from a well-known brand.

The implementation of VR environment increases the accuracy of all measurements, e.g. how long the subject views a given product, the exact location of objects as well as the subject in the shop. In addition, data recording on the computer helps recreate the entire history of the customer movement around the store as well as any actions related to, for example, picking up and putting given products into the basket. The most important advantage of the software solution, compared to the real shop described in Sam Hui's study, is that there is no use of complicated cameras, sensors and algorithms to determine the

customer location in a store and to record any actions taken by such person or by other customers in the store (Hui et al., 2013).

It should also be mentioned that a modern VR environment created, for example, in Unity software, allows research costs to be minimised. Conducting research in a real shop can often involve not only the potential cost of renting a shop, but also the inability to 'move' the shop to another location, which involves travel costs. Using a computer, VR hardware and a software environment enables the research to be carried out in any suitable location without the need for respondents to travel or to bear the cost of renting a shop. In our study, we used the VR laboratory located at the University of Szczecin.

One article examining consumer behaviour in a VR shop is a study by M. Siegrist et al. (Siegrist et al., 2019). They present two studies comparing customer behaviour in a real shop and in a virtual reality shop when selecting a particular product. It should be added that, as in our study, they also informed their subjects that they had a specific amount to spend - in their case it was 10 Swiss francs (Siegrist et al., 2019). However, their study significantly differed from ours. They were limited to only one type of product - breakfast cereal (all the brands they used were original brands from Swiss shops). It should also be added that the researchers stated that the first study was limited to a small slice of the prepared VR shop, in the second study customers were able to navigate through the entire virtual shop, but only breakfast cereal products were available. Furthermore, in the first study in the VR environment, subjects had to ask for product information to be displayed, which appears automatically in our experiment once the product is picked up. We also believe that being limited to one type of product cannot fully reflect in-store behaviour, as it must be assumed that a respondent may not buy a particular product, e.g. due to habits or health problems associated with such product. In the case of our shop, we did not use popular brands, in order to minimise the problem of choosing a product not based, for example, on a lower price, but on brand familiarity. The greatest advantage of our study is not only the complete freedom of the respondent in the shop, where he or she can move around the entire shop area, but also the very wide assortment - the respondent can choose, among other things, flowers, toys, books, but also chemical products, and even seafood. Therefore, we can research one or many specific products, during the normal shopping process, when the customer is shopping for a variety of goods.

Finally, a very important element of the study by Siegrist et al. should be added - they proved that customer behaviour in a VR shop did not significantly differ from behaviour in a real shop (Siegrist et al., 2019). Therefore, this conclusion provides additional support for our study.

We would also like to add that Siegrist et al. used VR goggles for research in the virtual reality environment (Siegrist et al., 2019). We mention this because of cases where researchers, instead of using goggles to simulate the environment, use, for example, computer monitors displaying simulator images on them (Huang, Backman, Backman, & Chang, 2016). Therefore, a distinction should be made between the use of a full set of virtual reality goggles and the use of computer screens.

We would also like to refer to a study by A. Schnack et al describing consumer behaviour in a VR shop. As it is in our case, they used a shopping list for the subjects containing specific food items, but they used the technique of presenting the printed shopping list to the subjects before entering the shop (Schnack, Wright, & Holdershaw, 2020). In our

study, we used the technique of displaying the shopping list any time the respondent was in the VR environment. This is based on the assumption that the list should be available to the respondent at any time, because a person who can remember what to buy does not need the list in order to make a purchase. The person using the shopping list may want to use it at any time to check if all the products are already in the basket.

Apart from objective aspects in analysing consumer behaviour, other issues are important as well, i.e. emotions accompanying shopping (Schwarz, Strack, Kommer, & Wagner, 1987; Schwarz, 1990; Escadas, Jalali, & Farhangmehr, 2019). Psychologists believe that the decision to buy is often based on feelings (Zimbardo & Gerring, 2017). It is on the grounds of feelings that a consumer compares, checks, purchases products (Lerner & Keltner, 2000; Isen, 2001; Cohen, Pham, & Andrade, 2018; Kahneman, 2012). Decisions based on emotions are often irrational (Pradeep, 2011; Mruk, 2017). Therefore, it is becoming increasingly more common for companies to gather multi-dimensional data on consumers in order to accurately appeal to their tastes and expectations (H. Hall, 2014; Gregor & Wdowiak, 2016; Chkoniya, 2020; Pluta-Olearnik & Szulga, 2022).

Therefore, summing up theoretical considerations, the authors notice and appreciate the huge theoretical and methodological achievements in the field of research on consumer behaviour, including in particular the issue of rationality, having the shopping list, or planned and unplanned purchases. However, they also assume that the research methods used so far in the issue presented are currently not sufficient, because thanks to new technological achievements they could be supplemented and improved. Therefore, an attempt was made to expand knowledge by using different configurations of methods in the study conducted than those used so far, in order to obtain a comprehensive picture of the modern consumer.

Currently, an important question is, irrespectively of the approach presented to the very understanding of rationality, how a rational individual makes choices? A confrontation of theories and models with every-day behaviour indicates that the decision-making process is highly complex. It arises from the fact that both the economic determinants, along with the increased importance of non-economic factors, particularly psychological ones, play an important role in shaping rational attitudes. Therefore, over the last 20 years the development of neuro-economics and neuro-marketing could be observed along with the research methods related to these sciences (Senior & Lee, 2008; Hubert & Kenning, 2008; Fugate, 2008; Foxall, 2008; Garcia & Saad, 2008; Ariely & Berns, 2010; Gang, Lin, Qi, & Yan, 2012; Hackett & Foxall, 2018). Consumer choices concerning the purchase of goods and services are described within the scope of neuro-marketing, including also the determination of how rational these choices are (Richard & Laroche, 2011; Page, 2012; Gutmann, 2015, 2017; Lawes, 2018). In the study presented, the focus was placed on the use of modern research methods and an attempt was made to indicate how far these methods can be employed in assessing rational consumer behaviour.

METHODOLOGY

Despite the fact that virtual reality technology has existed since the 1960s, it was only the development of the technology in the 21st century that enabled to precisely conduct research with the use of VR technology (Wohlgenannt, Simons, & Stieglitz, 2020). Development of

VR environment makes it possible to carry out research in any environment. Combining VR technology with EEG constitutes a relatively new research method. In his article, J. Tromp (Tromp, Peeters, Meyer, & Hagoort, 2018) indicates that researchers have been using the environment simulating vehicle driving since 2000 as one of the most popular research directions.

The popularization of research with the use of the above-mentioned techniques as well as the development of technologies caused that many branches of science started using them. They are employed very broadly in medicine. For instance, they have found an application in rehabilitation of the physically disabled (Cheron et al., 2012; Lazarou, Nikolopoulos, Petrantonakis, Kompatsiaris, & Tsolaki, 2018; Tan et al., 2020) as well as the mentally disabled (Cho et al., 2002; Roesmann et al., 2022). Furthermore, other areas include research on how individuals behave in a given space (e.g. in a labyrinth) (Kober, Kurzmann & Neuper, 2012), studies of drivers' behaviour while driving a vehicle (Zhao, Zhang & Cichocki, 2009; De Blasiis, D'Anna & Conforto, 2021), studying consumer preferences (Guo & Elgendi, 2013; Mann, Liu-Thompkins, Watson, & Papelis, 2015; Baceviciute, Lucas, Terkildsen, & Makransky, 2022), as well as studies on how people communicate (Tromp et al., 2018). The literature presented clearly demonstrates that the research technique composed of VR and EEG has become one of the most widely applied modern research methods. Such high-tech solutions enable researchers to obtain increasingly more accurate results and to study new spheres of life. The source literature indicates that rather sparse research has been conducted so far on consumer preferences and behaviour with the use of VR and EEG (Siegrist et al., 2019).

The present study was carried out from June 2021 to August 2021. The stages of the procedure within the scope of the adopted research formula were consistent with the methodology of in-depth interviews and the experiments described in literature and by the authors in a separate paper (Słupińska, Duda, & Biercewicz, 2021). Research based on the method of an interview was developed in the 1960s and the 1970s (Lewandowska, 2004). This method enables to obtain data and, through direct verbal contact with an individual, provide the information regarding the problems of interest to the researcher (Góralski, 1994). Thanks to such subjective approach and the possibility of a free conversation, the person being interviewed openly shares their observations and feelings as well as their own experiences.

Within the scope of the first stage, the study participants were invited to take part in an interview to be conducted at a focus workshop. The method of in-depth interviews (dyads and triads) was adopted. The choice of the method of carrying out interviews was dictated by the period in which the study was carried out, i.e. the time of increased restrictions resulting from the Covid-19 pandemic. A projection method was employed, which enabled to conduct an analysis of the aspects of conscious and unconscious spheres. The method required the use of long-term memory through which participants were expected to recreate their most often frequented store, then a moderator conducted an interview with them on their shopping habits, whether they prepared a shopping list, how they moved around the store, how they chose products. After the interview had been completed, participants were invited to take part in the 2nd stage that involved an experiment in a virtual store.

The participants were directed to a virtual reality laboratory, where they were introduced to a virtual world. Additionally, 35 people that had been involved in the previous stage

partook in this study. It was a conscious decision which enabled to observe differences occurring in the conscious and unconscious sphere. Due to the small number of participants, the study conducted was a pilot study At the beginning, the research subjects were asked to fill in a survey questionnaire indicating their preferences regarding the manner of making a purchase, defining themselves as a customer type and declaring whether or not they tend to use a shopping list on an every-day basis. The study participants were divided into 2 groups: those who did shopping in accordance with the shopping list drawn up by the researchers and who had PLN 50 at their disposal (20 individuals), and those who were not given any shopping list and who had PLN 50 at their disposal (15 individuals). Additionally, the groups were further divided based on the declarative statements made during individual interviews into those who regularly did shopping with a shopping list and those who did not use such support.

The groups were divided as follows:

1st group - individuals shopping without a list, who did not use the list in the VR environment (10 people);

2nd group – individuals shopping with a list, who used the list in the VR environment (12 people);

3rd group - individuals shopping with a list, who did not use the list in the VR environment (8 people).

4th group - individuals shopping without a list, who used the list in the VR environment (5 people);

All four groups of the subjects observed were expected to do daily shopping. The division into groups and sub-groups is part of a regular procedure of an experimental VR study (Słupińska, Duda, Biercewicz 2021). As group 4 was underrepresented, it was not taken into account in the analyses. The study was conducted in Virtual Reality (VR) environment, which enabled the analysis of the unconscious sphere of behaviour. The environment was planned in such a way so as to reliably recreate a traditional FMCG store. The main objective was to create situations that would reflect the ones encountered by the study subjects in the real world. The precondition for joining in the study was granting an informed consent to participate in the VR study. The respondents were advised on the manner of conducting the experiment.

This division gives additional information about human behaviour based on past experiences and habits, which are a form of unconscious behaviour. This allows one to check to what extent it can introduce this disturbance in the decision-making process. Conscious behaviour is considered to be people's declarations about their shopping behaviour while unconscious aspects are their actual behaviour.

In addition, the afore-mentioned experiences influence unconscious behaviour. People, by definition, act in accordance with the method they adopt on a daily basis.

The time spent in the store was used as the controlled parameter in the experiment. Audio announcements were used to inform about the closing of the checkout, which occurred after 15 minutes of the respondent's stay in the store. Announcements heralding the closing of checkouts occurred 3 minutes before the end of the time limit allotted and communicated that participants had 10 minutes until the closing of checkouts.

The restriction in the form of message transmission was intended to assess consumer behaviour under time pressure, i.e. to what extent the consumer will complete the purchase,

and to what extent he will abandon it and head to the checkout. The message setting was arranged so as not to interfere with the additional study of spending time in the store, as the pilot study estimated the time average for the final moment of shopping, rather than interrupting the entire shopping process.

This variable was chosen as a factor that could influence the behaviour of participants, especially the ones without the shopping list.

Virtual Reality Environment

The pilot study was carried out in a virtual store developed in Unity 2019.4.6f1 game engine. When developing the store, a demonstration scene was used along with models from the asset of Supermarket interior with LOD. The models of independent characters playing the role of customers were made with the use of MakeHuman software, based on sets of clothing on an OpenSource licence. Some models of the facilities were made or modified in Blender programme.

The virtual store represents a supermarket comprising three aisles with four rows of shelves in each of them. One of the island displays offered products on promotion.

The first aisle featured the following departments: fruit, vegetables, cheeses, cured meats, meat, frozen products, spices, kitchenware and a promotion island display. The next aisle featured the following departments: toiletries, toys, cleaning products, books, tins, pasta, sweets, seafood. The third aisle offered soft drinks, alcohols, dairy products, bakery products.

The study subjects were placed at a starting point (Figure 1). After completing their shopping, the participants had to reach (or be transferred to, if they ran out of time) to checkout number one (marked as “the end”). Goods in the store were placed in accordance with retail merchandising principles.

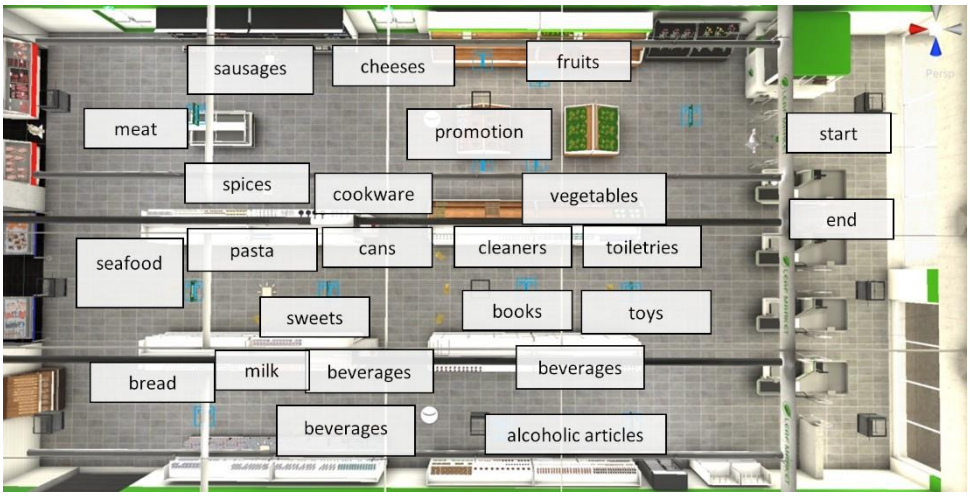

Figure 1. Goods placement.
[Source: Own elaboration]

The store had 34 zones designated in which study participants could move (Figure 2). The dimension of each zone was not bigger than 4.5x3.5m.

Figure 2. The areas in which the player could move around.
[Source: Own elaboration]

The study subject was accompanied by a model of a shopping trolley. Similarly as in a real store, goods could be put in and taken out of the trolley. Each product that could be held, was subject to the laws of physics: it could be dropped, thrown, etc. When an item was picked up, its price was displayed (Figure 3).

Figure 3. Displaying product price.
[Source: Own elaboration]

The study subject who finished shopping had to go to the area next to checkout number one. Entering the checkout area resulted in adding up the total amount to be paid for shopping. Finally, the study participant had to choose the payment method (Figure 4).

Figure 4. Selecting the payment method.
[Source: Own elaboration]

In order to make the experience as realistic as possible, independent characters, acting as store customers, were introduced into the virtual reality environment. There were five such characters in the store: two men and three women. They moved around at random among designated areas in front of the shelves.

Every event in the virtual reality environment was recorded and saved as an *.xls (xml version) file. Events included, inter alia: picking a product up from the shelf, putting it away in the trolley, entering the area designated by the researchers, coming close to an independent character, etc.

Experimental Design

At the beginning of the study, research participants were shown an instruction film footage on how to move around the store, how to use VR controllers. After viewing the instruction film footage, VR goggles were put on the study participants to allow them to practice moving around the store. To that end, a demo version of the store was run, in which the store content was limited to only a few shelves. Following that, the participants were fitted with the entire equipment used during the study (an EEG cap and VR goggles). Then, recording of the images seen by the participant was initiated, along with the EEG signal and the VR environment.

At the beginning, study participants were presented with a black screen for 60 seconds, during which time they were asked to calm their senses, and thus their brainwaves. Next a store simulation was launched, in which participants were placed at the starting point (fig.1). During the study, each participant did shopping by putting selected products into the trolley. Products could be taken out of the trolley and put back on the shelf at any time. While a product was held in hand, its price was displayed. The individuals doing shopping with the shopping list could choose to display their shopping list by pressing the right button on the

controller. The list comprised: bananas – 2 pieces, yoghurt – 3 tubs, pizza – 1 piece, bread – 1 piece, water – 1 piece, fish – 2 pieces and cheese – 1 piece. It was assumed in the study that individuals shopping with the list had a specific list of products to buy and despite a limited shopping budget, they treated it as a task that needs to be accomplished. Such a claim was tied to the results of the qualitative research. The individuals who indicated they did shopping efficiently, not requiring a lot of time at the store, were quite strongly co-related to the individuals who previously declared that they prepared a shopping list or that they did standard shopping that did not need to be put down, but which they treated as if products were put on the list. Additionally, the individuals who specified that they tend to shop with the shopping list, paid less attention to the environment – signboards, price promotions. In the replies given by the individuals referring to a constant arrangement, task orientation and constant shopping route were stressed: "I do not pay attention to signboards, I am task-oriented when I shop", "I enter a store, go to a specific shelf and then head towards the checkout", "I am task-oriented when I shop. I walk along my regular route. (…) In this way I do not waste time."

DATA ANALYSIS

VR goggles (HTC Vive Pro Eye) were chosen for the study. Moreover, a wireless Enobio® EEG systems – Neuroelectrics EEG cap was used. It is fitted with 20 electrodes placed in accordance with 10-20 system at the following points P7, P4, Cz, Pz, P3, P8, O1, O2, T8, F8, C4, F4, Fp2, Fz, C3, Fp1, T7, F7, Fpz. The data were registered with a sampling frequency of 500Hz.

All the analyses, with the exception of the presentation of the study participants' routes, were conducted with Matlab computing platform. The presentation of the study participants' routes in the VR environment was prepared with the use of C# language. EEGLAB and FieldTrip toolboxes, dedicated to the MatLab environment, were used for EEG analyses.

Registered EEG signals were subject to preliminary processing. Using EEGLab and FieldTrip, any interference from the power grid was filtered out, along with any artefacts related to, inter alia, eyeball movement, muscle movement, etc. The quality of the EEG signal was further verified and all of its low quality fragments were removed. In the next stage, a band filtration was employed, thanks to which the data in a subsequently used frequency range were isolated. It decreased the impact of any interference caused by the operation of VR goggles on the results of analyses.

Data analysis was based on the processing of data recorded by the VR environment and by recording devices. The analysis of the length of the routes covered was based on the records of VR goggles location. The total route covered by the study participant was calculated on the basis of the following formula:

$$d = \sum_{i=1}^{N_p-1} \sqrt{(x_i - x_{i-1})^2 + (z_i - z_{i-1})^2}, \quad (1)$$

where:

x_i, z_i – i-th goggles coordinates (y_i height is omitted),

N_p – number of registered positions;
d – route covered by a study participant.

In order to calculate the route with the exclusion of transfers between areas, the following formula was used:

$$d' = \sum_{i=1}^{N_p-1} \begin{cases} \sqrt{(x_i - x_{i-1})^2 + (z_i - z_{i-1})^2} & \text{when} \quad \sqrt{(x_i - x_{i-1})^2 + (z_i - z_{i-1})^2} \leq p \\ 0 & \text{when} \quad \sqrt{(x_i - x_{i-1})^2 + (z_i - z_{i-1})^2} > p \end{cases}, \tag{2}$$

where:
p – threshold defining a minimum distance of transfer between areas,
d' – route covered by the study participant, not taking into account any transfers between areas.

Before the indices were calculated, a preliminary signal processing was carried out. First, all interference was filtered out (for instance, the one coming from electric current sources). Then, all interference resulting from the working of the eye muscles and eyeball movement (Al-Fahoum & Al-Fraihat, 2014) was removed (the so-called artefacts (Fitzgibbon, Powers, Pope, & Clark, 2007; Romero, Mañanas, & Barbanoj, 2008)) using an independent component analysis (ICA (Jung et al., 2000)).

After such preliminary EEG signal processing, EEG data was synchronised with the registered events. Following that, a gamma band (25-40Hz) was isolated from the EEG signal with the use of a continuous wavelet transform, for which a global field power (GFP) was determined. On the basis of the GFP, *F* values were calculated for the Arousal-Valence indices (McMahan, Parberry, & Parsons, 2015) and they were substituted to the following formulas:

$$Arousal = \frac{F3_{beta} + F4_{beta}}{F3_{alpha} + F4_{alpha}}, \tag{3}$$

$$Valence = \left(\frac{F4_{alpha}}{F4_{beta}}\right) - \left(\frac{F3_{alpha}}{F3_{beta}}\right), \tag{4}$$

where:
F3 alpha – the signal obtained from F3 electrode with alpha wave record
F3 beta - the signal obtained from F3 electrode with beta wave record
F4 alpha – the signal obtained from F4 electrode with alpha wave record
F4 beta - the signal obtained from F4 electrode with beta wave record

The results obtained with the use of the above-mentioned formulas were calculated with the GFP and electromagnetic alpha and beta brainwave signals recorded during the study.

In their papers, the authors (A. McMahan, 2003; T. McMahan et al., 2015) point out that the above-mentioned Arousal-Valance model may also be used for analysing players'

involvement, but also their preferences. The value obtained of the Arousal index enables to determine whether the study participant is under stress (too high level) or whether they are bored (too low level) – it is an intensity index (Russell & Barrett, 1999; T. McMahan et al., 2015). In the same paper, McMahan (T. McMahan et al., 2015) emphasises that the Valance index is applied in order to determine negative and positive emotions. Defining the value of that variable enables to determine what emotions accompanied the study participant, e.g. whether it was sadness or happiness (T. McMahan et al., 2015).

RESEARCH RESULTS

It was assumed in the study that the individuals using the shopping list had a specific list of products to buy and despite limited budget allocated to shopping, they behaved in a task-oriented manner. The claim was linked with the results of the qualitative research. The individuals who indicated they did shopping efficiently, not requiring a lot of time at the store, were quite strongly co-related with the individuals who previously declared that they prepared the shopping list or that they did standard shopping that did not need to be put down, but which they treated as if products were put on the list. Additionally, the individuals who specified that they tend to shop with a shopping list, paid less attention to the environment, i.e. signboards, price promotions. In the replies given by the individuals referring to a fixed arrangement, task orientation and fixed shopping route were stressed: "I do not pay attention to signboards, I am task-oriented when I shop", "I enter a store, go to a specific shelf and then head towards the checkout", "I am task-oriented when I shop. I walk along my regular path. (…) In this way I do not waste time."

Data registered during the test conducted in VR made it possible to specify what route was covered by each study participant. The figure presents overlaid routes of the individuals shopping with and without the list. The figure shows that the movements of the individuals using the shopping list were more purposeful. They did not enter certain areas at all, while some areas were visited only by certain people. It was closely linked with the products found on the shopping list. In the case of people moving around without the list, their movement routes demonstrated which products they were willing to purchase more or less readily. Toys and toiletries can serve as a good example of that finding.

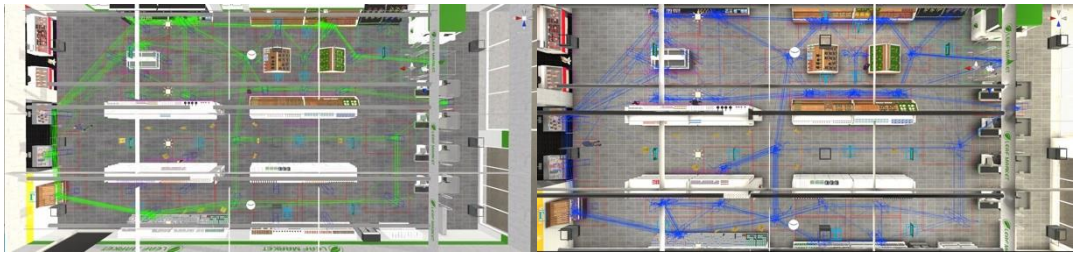

Figure 5. Routes covered by the study participants: a) moving around with the list (green lines); moving around without the list (blue lines).
[Source: Own elaboration]

All the following results and conclusions apply to the pilot group. They should be verified on a larger group of people. Due to the small number of respondents, statistical tests were not carried out and statistical significance was not determined. Information about the pilot group is presented in the methodology section.

A comparison of the distances covered by the individuals moving around with the list (average route was 250 m) and the individuals walking around without the list (average route was 243 m) indicates that the individuals from the former group covered a longer distance. However, if the distances related to moving between areas are ignored (it gives 75 m with the list and 82 m without the list, respectively), the conclusion is that the individuals using the list covered a smaller distance. Comparing these data, the conclusion can be drawn that individuals shopping with the list moved between areas a lot. Furthermore, it does not refer to all the individuals to the same degree, which was demonstrated by significant values of standard deviation: 82 (with 64 for the individuals shopping without the list). The route taken by a certain group of people was highly non-optimal, they covered very long distances between the instances of putting subsequent products into the trolley. There were far more such individuals among men (average route length was 273, with standard deviation of 77) than among women (210, 61, respectively).

The fact that the individuals moving around without the list covered a greater distance, if the distance related to moving between areas is ignored, indicates that they covered a greater route within the areas themselves. It means that they walked alongside the shelves much more. It was linked most likely to them looking through and comparing similar products. Those people were more focused on making a better choice of a product than the individuals shopping with the list. The virtual reality environment provided the participants with only two types of information: visual information (appearance) and price. It means that they may have been looking for products more attractive in terms of appearance and/(or) price. Women were more concentrated on making a better choice (average route length for women was 90) in relation to men (whose average route length was 69). Therefore, one may conclude that women are more sensitive to product appearance and/(or) price.

Following that, specific groups of people were analysed who at the stage of the qualitative research defined themselves as individuals shopping with the list and without the list, as well as the ones who in VR were tasked with doing shopping with the list and doing shopping according to their free choice. Therefore, 4 analysed groups can be specified:

1. individuals shopping without the list, who did not use the list in the VR environment (10 people);
2. individuals shopping with the list, who used the list in the VR environment (12 people);
3. individuals shopping with the list, who did not use the list in the VR environment (8 people).

The fourth group was removed from the analysis of the results, due to an insufficient number of respondents.

Figure 6 shows the arrangement of products in the shop with their order number in the list. The majority of people using the list concentrated on selecting the next products on the list, generally ignoring the possibility to change this order. Among the respondents, 5 people shopped exactly in the order indicated on the list and 7 people made only one deviation from

this order. In the shop, there were 3 products next to each other: yoghurt, pizza and cheese, but only yoghurt and pizza were next to each other on the list. Only 2 people took the 3 products at once, 2 people took the yogurt and cheese at once, but came back later for the pizza. On the other hand, as many as 8 people took the yoghurt and pizza and came back later for the cheese. This indicates a strong influence of the list on the order of shopping.

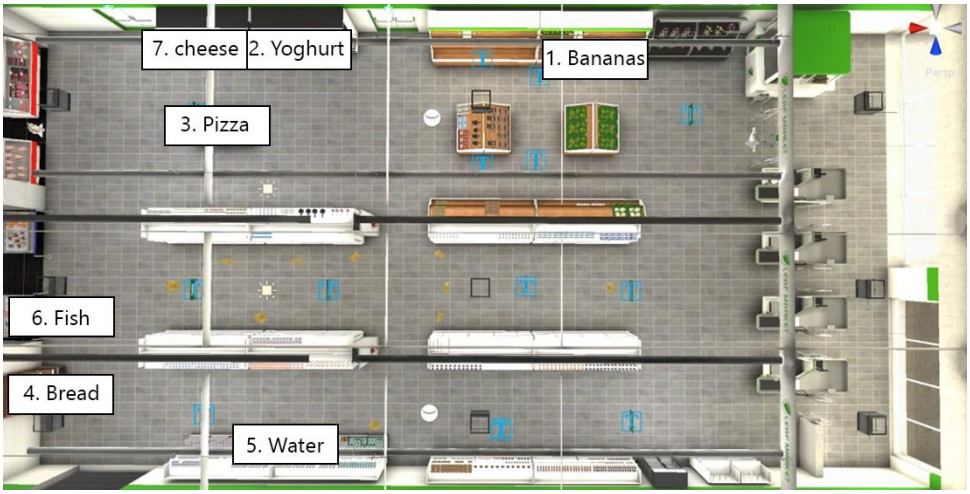

Figure 6. Arrangement of individual items present on the shopping list. The items were presented as they were on the shopping list.
[Source: Own elaboration]

The third group was introduced in order to check how the shopping process would be affected by upsetting a person's shopping habits. The average spending in the first two groups (first and second) was more or less similar (PLN 79.09 and PLN 72.18, respectively). However, the standard deviation for the first group was slightly greater (PLN 45.75 and PLN 31.74, respectively). It probably resulted from the fact that the group shopping without the list enjoyed greater freedom in selecting products, which translated into a greater spread of spending. The greatest average expenditure (PLN 100.36) and the greatest standard deviation (PLN 63.91) was observed in the case of the third group. The results obtained indicate that the lack of the shopping list, which participants were used to, probably led some of them to pick the products they liked, rather than the ones they actually needed. That is why they easily exceeded the budget allocated to them. The group also included individuals who maintained shopping "discipline", which translated into low spending on the products purchased.

When comparing our results obtained with those of Sam Hui and Jeff Inman's study, similarities can be found. For our first two groups and their study, significant overlap can be seen for shopping with and without the list. Their results indicated that shopping with the list could reduce additional spending on unplanned items by around 21% (they did not report the difference in price) (Huang, Hui, Inman, & Suher, 2012). In the case of our study, the difference in expenditure between group 1 and group 2 is around 10% (PLN 72.18 and PLN 79.09). It can therefore be concluded that, in both cases, the shopping list drawn up in advance helped to reduce unplanned expenditure.

The average duration of the shopping done by members of the first group (9 minutes 46 seconds) was distinctly longer than the time the members of the second group needed on their shopping (7 minutes 59 seconds) with a comparable standard deviation (2 minutes 41 seconds and 2 minutes 11 seconds, respectively). The result demonstrates that the individuals using the shopping list were more organized, since they did not need to ponder over what products they had to buy, but only the product of which manufacturer to choose. Forcing the people to use the shopping list, who normally did not use it, did not result in reducing their shopping, quite the reverse, their shopping time was extended. The average time of shopping for the third group was 9 minutes 30 seconds with a standard deviation of 3 minutes 17 seconds, which constitutes a significant increase in relation to the second group. This indicates that a certain proportion of the study participants required more time to search for products.

According to the study by S.Hui and J. Inman, the time spent in a shop influences purchasing decisions. According to their calculations, a clear conclusion emerged from the results of the study - if a respondent thinks about buying a product for 10 seconds, according to the study, the chance to buy it increases by 2%. If we assume that every 10 seconds spent in a shop, according to S.Hui and J.Inman's study, results in a 2% increase in the chance of buying an unplanned product, we can try to compare this with our study (Huang et al., 2012).

For the first study group without the list, the time spent in the shop is 9 minutes and 46 seconds, and for the group with the list it is 7 minutes and 59 seconds. The difference between the groups is therefore 107 seconds. After calculating the percentage, based on the study by S. Hui and J. Inman - we obtain a value of 21.4% (Huang et al., 2012). Comparing the values with the amounts for the two groups respectively (group 1 - PLN 72.18, group 2 - PLN 79.09) yields a difference of 21%. Therefore. we obtain overlapping results - 21.4% (time) and 21% (expenditure). Therefore, we can conclude that every 10 seconds more spent in the shop by people without the list increased their spending by 2%, according to which the difference in spending actually coincides with the value calculated on the basis of the survey results. The distance covered by study participants, without taking into account teleportation (i.e. moving around in the vicinity of store shelves) was the shortest in the second group and it equalled 64.28 metres with a standard deviation of 26.6 metres. It proves that there is strong orientation towards task accomplishment: the purchase of all the products on the list with little need to look for products not included on the list. The average distance covered, including teleportation, was 235.46 meters with the highest standard deviation of 85.07 meters, which demonstrates that some individuals did their shopping in a non-optimal fashion. Most likely, they were searching for products in the order in which they were enumerated on the list. Members of the first group shopping without the list covered a greater distance without taking teleportation into consideration – 80.62 metres (with a standard deviation of 30.93 metres) and taking teleportation into account – 261.32 metres (with a standard deviation of 63.7 metres). Forcing the people who typically do not shop with the list to use it, had virtually no impact on changing the distance they covered in the vicinity of store shelves (average distance covered without taking teleportation into account: 80.19 metres with a standard deviation of 9.41 metres). In turn, the distance covered including teleportation decreased to 251.71 metres and the standard deviation to 40.42. It demonstrates that those individuals moved less across greater distances. The members of the third group covered a greater distance in comparison to the members of the second group without taking teleportation into consideration (83.21 metres with a standard deviation of 23.85 metres), but

they covered a smaller distance if teleportation was to be accounted for (219.23 metres with a standard deviation of 65.11 metres). It demonstrates that they moved around more in the vicinity of the store shelves, which may constitute proof that they took more time to consider what they had to buy. They moved less across greater distances, thereby likely eliminating wandering around in search of the places where the goods on the list may be located.

Again, our results can be compared with the study by S. Hui and J. Inman. They showed in the study of the walking route in shops that if the route was increased by 10% (in their case it was about 50m) the increase in unplanned expenditure could be 7% (Huang et al., 2012). In our study, the subjects with the list (group 2) walked, without teleportation between areas, 64.28m, and the subjects without the list (group 1) walked 80.62m - a difference of 21%. On the other hand, comparing the result including teleportation, i.e. 235.46 m (group 2) and 261.32 m (group 1), we obtain even 10% difference. This means in this case that the distance covered by the listless is greater and, as in the study by S.Hui and J. Inman, the expenditure also increased, in our study by the previously mentioned 10% (7% in their study) (Huang et al., 2012). This confirms to us that a greater distance travelled in-store increases shopping expenditure.

For the purpose of assessing emotions accompanying the study participants, average values of the Arousal-Valance indices where calculated for the moments during which study subjects held products in their hands. The averages were computed for the previously specified three groups. The results are presented in Table 1 and in Figure 2. On the basis of the results obtained, it can be concluded that the individuals shopping with the list and moving around in VR with the list experienced excitement when looking at products. Similar results were observed in case of the individuals shopping without the list and moving around in VR without the list, however the level of excitement they experienced was far lower. Whereas the remaining group of people who were forced to alter their shopping habits experienced frustration. The frustration was greater among those people who typically did shopping with the list, but who were instructed to shop without it in VR.

Table 1. Average values of the Arousal-Valence model calculated for the moment of holding products.

Daily shopping	**List**	**List**	**No list**
Shopping in VR	**List**	**No list**	**No list**
Average value of the Arousal index	0.199808	0.025175	0.038775
Average value of the Valence index	0.088057	-0.06967	0.017565

[Source: Own elaboration]

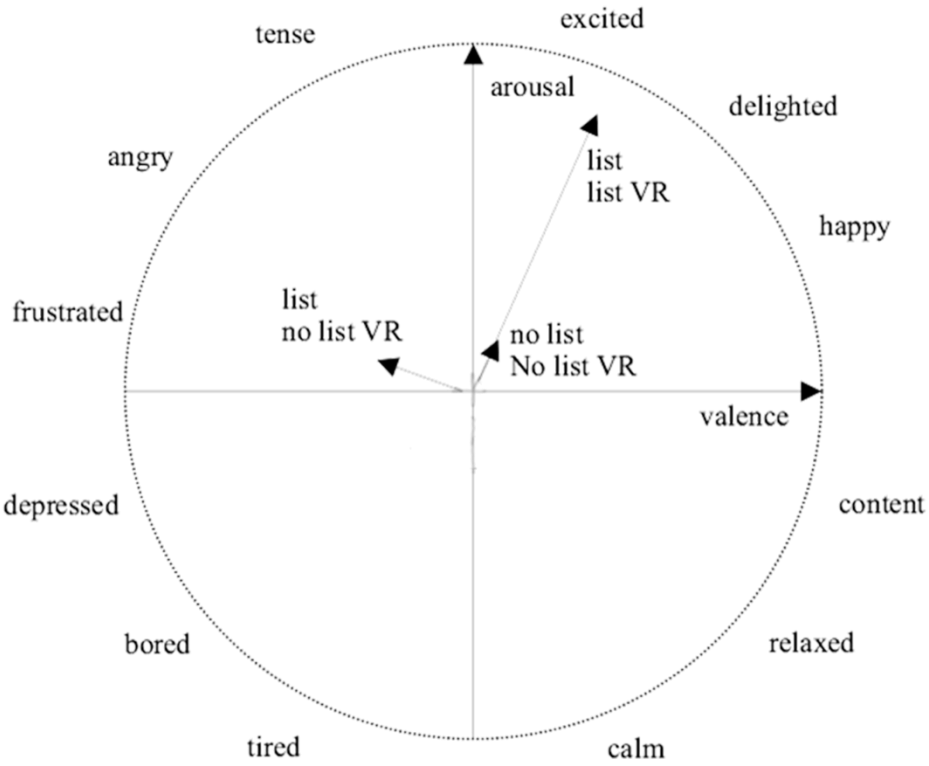

Figure 7. Emotional states for the four examined groups of people (emotion distribution according to Building Chinese Affective Resources in Valence-Arousal Di.
[Source: Yu, et al., 2016]

This result demonstrates that the emotions are indirectly dependent on the fulfilment of the shopping list, and that they directly arise from consumers' habits. A person acting rationally does not associate the performance of a regular activity with negative emotions.

DISCUSSION

The research results presented were meant to examine and demonstrate to what degree rational behaviour can determine consumers' behaviour in a shop from the perspective of drawing up the shopping list. Referring to the main and the supporting hypotheses adopted in the study, it can be concluded that the shopping list has a significant impact on consumers' behaviour. As demonstrated by the analyses, the shopping route taken by individuals with the shopping list is substantially shorter than that of the individuals shopping without the list, as it was assumed in hypothesis 1. Such individuals concentrate on the task when moving from point a to b, without paying much attention to the environment. Their focus was solely on comparing products of the same category.

However, it could be noted that the individuals who draw up a shopping list on a regular basis tended to be organized more quickly. In a situation in which they were not required to prepare a list, they still drew it up and got oriented more swiftly while making choices. They

confirmed their model of operation also in post-study interviews. When asked how they chose products, they referred to an objective set in advance: “I imagine that I shop for breakfast, dinner and supper”; “I thought what I wanted to eat for dinner and what products I required to prepare it”; “I was choosing the products that I buy on a daily basis”.

With regard to hypothesis 2, even though each of the participants was in the given store space for the first time, the individuals who were offered the shopping list and who prepared one for their regular shopping crossed the store much faster than the remaining participants. Those groups where highly task-oriented when moving around the store and they were focused on accomplishing the goal set to them, and not on becoming familiar with the space or the offer.

The greatest surprise involved the results of the study concerning hypothesis 3, which demonstrated that there is no explicit relationship between expressing positive and negative emotions by the individuals equipped with the shopping list or those shopping without it. Those people who were moving around the shop without the list were less excited than those with the list. Such behaviour may demonstrate the attitude they have to making a purchase. A goal and a need to accomplish the task provides more positive emotions and excitement than walking aimlessly around the store. It shows that habits strongly determine our emotions.

The results demonstrated substantially that the shopping list may constitute a factor that determines rational consumer behaviour. Since it possesses all the characteristics that affect task-oriented behaviour, bringing a consumer closer to the assumed final result in a quick and efficient manner without unnecessary additional emotions.

The research results presented cover the first group of the experiment conducted, which was selected according to the adopted criteria. Its results provided the basis for the continuation of the research, which is currently being carried out. Expanded conclusions will be presented in further work of the team. The number of studied individuals needs to be expanded in particular, since after dividing the group into four sub-groups, the number of research subjects in the examined sub-groups occurred to be insufficient. For that reason, the conducted research may only be recognized as a pilot study.

For this reason, conducting significance tests was deemed inappropriate by the authors, as with a non-representative group in the subgroups in question, the results would not be fully objective and appropriate.

The study is of great cognitive value from the point of view of the direction of further in-depth research assumed by the team.

CONCLUSIONS

Everyday rush, the need to make quick choices have a big impact on consumer behaviour. Doing shopping could be treated as a way of departing from regular task-oriented approach to that activity. It additionally becomes a category in which decisions are made rationally, and thereby swiftly, schematically, or they are focused on achieving a clearly-defined goal. Such an approach chiefly concerns those people who treat shopping as a regular activity, in which a shopping list enables them to organize and perform the task quickly.

On the other hand, thanks to the application of a formula assuming the shape of a shopping list, those people are less prone to the stimuli addressed to them as part of price

promotions and merchandising activity. Consumers make decisions in a manner that is better thought out, and thus rational. Yet, it needs to be pointed out that there are individuals who use the shopping list in an irrational fashion, which manifests itself in substantial distances they cover in a store. Although their shopping decisions may be rational, the order in which they look for products is most likely irrational. Their behaviour ought to become the subject of a separate study.

Decision-making is directly related to goal accomplishment. Rationality requires a consumer to possess the skill of seeking alternative solutions without experiencing negative emotions that may accompany it. Therefore, as the study showed, frustration is the effect of the inability to follow a known or adopted method of operation. Having a shopping list enables task-oriented shopping, which may involve substitution scenarios. Furthermore, it is worth noting the emotions, shopping duration, and rationality from the standpoint of visual merchandising. Thanks to the distinct marking of given products and their unchanging arrangement, a customer who would seem to be less valuable from an economic standpoint, may become more loyal. Thanks to the familiarity with the arrangement of products on the shelves, such customer is more willing to return and speak positively about their store. This sphere constitutes one of the topics analysed by the authors in further research. The presented reflections and directions for further activities are based on the current observations expressed by the study participants during their in-depth interviews. That material will be the subject matter of subsequent papers.

FUNDING

The project is financed within the framework of the program of the Minister of Science and Higher Education under the name „Regional Excellence Initiative” in the years 2019 – 2022; project number RID/IZ/2021/1/89; the amount of financing PLN 24,000.00.

REFERENCES

Abratt, R., & Goodey, S. D. (1990). Unplanned buying and in-store stimuli in supermarkets. *Managerial and Decision Economics*, *11*(2), 111–121.

Ahmed, S., & Ting, D. H. (2019). The shopping list in goal-directed shopping: Scale development and validation. *The Service Industries Journal*, *39*(5–6), 319–342. https://doi.org/10.1080/02642069.2018.1532997

Al-Fahoum, A. S., & Al-Fraihat, A. A. (2014). Methods of EEG signal features extraction using linear analysis in frequency and time-frequency domains. *ISRN Neuroscience*, *2014*, 730218. https://doi.org/10.1155/2014/730218

Allais, M. (1953). Le Comportement de l’Homme Rationnel devant le Risque: Critique des Postulats et Axiomes de l’Ecole Americaine. *Econometrica*, *21*(4), 503. https://doi.org/10.2307/1907921

Antonides, G., & van Raaij, W. F. (Eds.). (2002). *Zachowanie Konsumenta. Podrecznik Akademicki*. Wydawnictwo Naukowe.

Ariely, D., & Berns, G. S. (2010). Neuromarketing: The hope and hype of neuroimaging in business. *Nature Reviews Neuroscience*, *11*(4), 284–292. https://doi.org/10.1038/nrn2795

Arrow, K. J. (1982). Risk perception in psychology and economics. *Economic Inquiry*, *20*(1), 1–9. https://doi.org/10.1111/j.1465-7295.1982.tb01138.x

Arrow, K. J. (1986). Rationality of Self and Others in an Economic System. *The Journal of Business*, *59*(4), S385–S399.

Arrow, K. J. (1990). Economic Theory and the Hypothesis of Rationality. In J. Eatwell, M. Milgate, & P. Newman (Eds.), *Utility and Probability* (pp. 25–37). London: Palgrave Macmillan UK. https://doi.org/10.1007/978-1-349-20568-4_8

Baceviciute, S., Lucas, G., Terkildsen, T., & Makransky, G. (2022). Investigating the redundancy principle in immersive virtual reality environments: An eye-tracking and EEG study. *Journal of Computer Assisted Learning*, *38*(1), 120–136. https://doi.org/10.1111/jcal.12595

Bassey, S. A., Okoi, I. O., Bassey, E. I., & Wirawan, H. (2022). *Relativism and Rationality in The Social Sciences:* Presented at the Interdisciplinary Conference of Psychology, Health, and Social Science (ICPHS 2021), Makassar, Indonesia. Makassar, Indonesia. https://doi.org/10.2991/assehr.k.220203.022

Baumol, W. J. (1951). The Neumann-Morgenstern Utility Index—An Ordinalist View. *Journal of Political Economy*, *59*(1), 61–66. JSTOR. Retrieved from JSTOR.

Bayton, J. A. (1958). Motivation, Cognition, Learning—Basic Factors in Consumer Behavior. *Journal of Marketing*, *22*(3), 282–289. https://doi.org/10.1177/002224295802200305

Bazerman, M. H., & Messick, D. M. (2001). On the power of a clear definition of rationality. In *Research in Ethical Issues in Organizations* (Vol. 3, pp. 97–101). Bingley: Emerald (MCB UP). https://doi.org/10.1016/S1529-2096(01)03008-5

Becker, Gary S. (1962). Irrational Behavior and Economic Theory. *Journal of Political Economy*, *70*(1), 1–13. https://doi.org/10.1086/258584

Becker, Gary S. (1976). *The economic approach to human behavior* (Vol. 803). University of Chicago press.

Becker, Gary Stanley. (1990). *Ekonomiczna teoria zachowań ludzkich*. Państ. Wydaw. Naukowe.

Biliciler, G., Raghunathan, R., & Ward, A. F. (2022). Consumers as Naive Physicists: How Visual Entropy Cues Shift Temporal Focus and Influence Product Evaluations. *Journal of Consumer Research*, *48*(6), 1010–1031. https://doi.org/10.1093/jcr/ucab042

Blackburn, S. (2004). Oksfordzki słownik filozoficzny,(tł. C. Cieśliński, P. Dziliński, M. Szczubiałka i J. Woleński). *Warszawa: Wiedza Powszechna*.

Block, L. G., & Morwitz, V. G. (1999). Shopping Lists as an External Memory Aid for Grocery Shopping: Influences on List Writing and List Fulfillment. *Journal of Consumer Psychology*, *8*(4), 343–375. https://doi.org/10.1207/s15327663jcp0804_01

Boudon, R. (2003). Beyond Rational Choice Theory. *Annual Review of Sociology*, *29*(1), 1–21. https://doi.org/10.1146/annurev.soc.29.010202.100213

Bullock, A., Stallybrass, O., Trombley, S., Eadie, B., & Adamiec, M. (1999). *Słownik pojęć współczesnych*. Książnica.

Chase, V. M., Hertwig, R., & Gigerenzer, G. (1998). Visions of rationality. *Trends in Cognitive Sciences*, *2*(6), 206–214. https://doi.org/10.1016/S1364-6613(98)01179-6

Cheron, G., Duvinage, M., De Saedeleer, C., Castermans, T., Bengoetxea, A., Petieau, M., … Ivanenko, Y. (2012). From spinal central pattern generators to cortical network: Integrated BCI for walking rehabilitation. *Neural Plasticity*, *2012*. Scopus. https://doi.org/10.1155/2012/375148

Chkoniya, V. (2020). Challenges in Decoding Consumer Behavior with Data Science. *European Journal of Economics and Business Studies*, *6*(3), 77. https://doi.org/10.26417/897ovg79t

Cho, B. H., Lee, J. M., Ku, J. H., Jang, D. P., Kim, J. S., Kim, I. Y., … Kim, S. I. (2002). Attention Enhancement System using virtual reality and EEG biofeedback. *Proceedings IEEE Virtual Reality 2002*, 156–163. https://doi.org/10.1109/VR.2002.996518

Cohen, J. B., Pham, M. T., & Andrade, E. B. (2018). The nature and role of affect in consumer behavior. In *Handbook of consumer psychology* (pp. 306–357). Routledge.

Concari, A., Kok, G., & Martens, P. (2020). A Systematic Literature Review of Concepts and Factors Related to Pro-Environmental Consumer Behaviour in Relation to Waste Management Through an Interdisciplinary Approach. *Sustainability*, *12*(11), 4452. https://doi.org/10.3390/su12114452

De Blasiis, M. R., D'Anna, C., & Conforto, S. (2021). Assessment of Drivers' Risk Levels Using a Virtual Reality Simulator. In N. Stanton (Ed.), *Advances in Human Aspects of Transportation* (pp. 26–33). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-80012-3_4

De Mooij, M. (2021). *Global marketing and advertising: Understanding cultural paradoxes*. Sage Publications.

Dima, I. C., Man, M., & Kot, S. (2010). Use of Abraham Maslow's motivation theory for setting consumers' satisfaction-non-satisfaction. *Polish Journal of Management Studies*, *2*, 132–138.

Drakopoulos, S. A. (1989). *THE IMPLICIT PSYCHOLOGY OF THE THEORY OF RATIONAL CONSUMER. AN INTERPRETATION*. University of GLASGOW.

Dudziak, S. (2013). Ekonomia behawioralna–interdyscyplinarne podejście do zachowań ekonomicznych. *Studia i Prace WNEIZ US*, (32/2), 23–36.

Engel, J., Blackwell, R., & Miniard, P. (1997). Consumer behavior. *New York: Dryden Press. Farr, A., & Hollis*, (1997), 23–36.

Engel, J. F., Miniard, P. W., & Blackwell, R. D. (2006). Consumer behavior 10th Edition. *Thomson South-Western. Mason. USA*.

Enis, B. M. (1977). *Marketing principles: The management process*. Goodyear Publishing Company.

Escadas, M., Jalali, M. S., & Farhangmehr, M. (2019). Why bad feelings predict good behaviours: The role of positive and negative anticipated emotions on consumer ethical decision making. *Business Ethics: A European Review*, *28*(4), 529–545. https://doi.org/10.1111/beer.12237

Ferber, R. (1977). Can Consumer Research be Interdisciplinary? *Journal of Consumer Research*, *4*(3), 189–192. JSTOR. Retrieved from JSTOR.

Fitzgibbon, S. P., Powers, D. M. W., Pope, K. J., & Clark, C. R. (2007). Removal of EEG Noise and Artifact Using Blind Source Separation: *Journal of Clinical Neurophysiology*, *24*(3), 232–243. https://doi.org/10.1097/WNP.0b013e3180556926

Foxall, G. R. (2008). Reward, emotion and consumer choice: From neuroeconomics to neurophilosophy. *Journal of Consumer Behaviour*, *7*(4–5), 368–396. https://doi.org/10.1002/cb.258

Freyd, J. J., & Gleaves, D. H. (1996). "Remembering" words not presented in lists: Relevance to the current recovered/false memory controversy. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*(3), 811–813. https://doi.org/10.1037/0278-7393.22.3.811

Fugate, D. L. (2008). Marketing services more effectively with neuromarketing research: A look into the future. *Journal of Services Marketing*, *22*(2), 170–173. https://doi.org/10.1108/08876040810862903

Galbraith, J. K. (1938). Rational and Irrational Consumer Preference. *The Economic Journal*, *48*(190), 336. https://doi.org/10.2307/2224960

Gang, D.-J., Lin, W., Qi, Z., & Yan, L.-L. (2012). Neuromarketing: Marketing through Science. *2012 International Joint Conference on Service Sciences*, 285–289. Shanghai, China: IEEE. https://doi.org/10.1109/IJCSS.2012.65

Garcia, J. R., & Saad, G. (2008). Evolutionary neuromarketing: Darwinizing the neuroimaging paradigm for consumer behavior. *Journal of Consumer Behaviour*, *7*(4–5), 397–414. https://doi.org/10.1002/cb.259

Ghosh, V. E., & Gilboa, A. (2014). What is a memory schema? A historical perspective on current neuroscience literature. *Neuropsychologia*, *53*, 104–114. https://doi.org/10.1016/j.neuropsychologia.2013.11.010

Green, D. P., & Fox, J. (2007). Rational choice theory. *Social Science Methodology. L.: Sage Publications*, 269–281.

Green, R. C., & Srivastava, S. (1986). Expected utility maximization and demand behavior. *Journal of Economic Theory*, *38*(2), 313–323. https://doi.org/10.1016/0022-0531(86)90121-3

Gregor, B., & Wdowiak, Ł. (2016). Istota oraz metody badań neuromarketingowych / Essence and methods of neuromarketing research. *Prace Naukowe Uniwersytetu Ekonomicznego We Wrocławiu*, (459). https://doi.org/10.15611/pn.2016.459.05

Griskevicius, V., & Kenrick, D. T. (2013). Fundamental motives: How evolutionary needs influence consumer behavior. *Journal of Consumer Psychology*, *23*(3), 372–386. https://doi.org/10.1016/j.jcps.2013.03.003

Guo, G., & Elgendi, M. (2013). A new recommender system for 3D e-commerce: An EEG based approach. *Journal of Advanced Management Science*, *1*(1), 61–65.

Gutmann, J. (2015). Book Review: Humanizing Big Data: Marketing at the Meeting of Social Science and Consumer Insight. *International Journal of Market Research*, *57*(3), 503–505. https://doi.org/10.2501/IJMR-2015-040

Gutmann, J. (2017). Book Review: Decoding the Irrational Consumer: How to Commission, Run and Generate Insights from Neuromarketing Data. *International Journal of Market Research*, *59*(1), 139–142. https://doi.org/10.2501/IJMR-2017-008

Hackett, P. M. W., & Foxall, G. R. (2018). Why Consumer Psychology Needs Neurophilosophy. In L. Moutinho & M. Sokele (Eds.), *Innovative Research Methodologies in Management* (pp. 29–48). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-64394-6_2

Hall, H. (2014). Nowy konsument a zmiany w metodach jego badania. *Prace Naukowe Uniwersytetu Ekonomicznego We Wrocławiu*, (336). https://doi.org/10.15611/pn.2014.336.16

Hall, R. E. (1990). *The rational consumer: Theory and evidence*. MIT Press.

Hand, C., Dall'Olmo Riley, F., Harris, P., Singh, J., & Rettie, R. (2009). Online grocery shopping: The influence of situational factors. *European Journal of Marketing*, *43*(9/10), 1205–1219. https://doi.org/10.1108/03090560910976447

Harsha Jayawilal, W. A., & Premeratne, S. (2017). The smart shopping list: An effective mobile solution for grocery list-creation process. *2017 IEEE 13th Malaysia International Conference on Communications (MICC)*, 124–129. Johor Bahru: IEEE. https://doi.org/10.1109/MICC.2017.8311745

Hartman, R. S., Doane, M. J., & Woo, C.-K. (1991). Consumer Rationality and the Status Quo. *The Quarterly Journal of Economics*, *106*(1), 141–162. https://doi.org/10.2307/2937910

Holotová, M., Nagyová, Ľ., & Holota, T. (2020). The impact of environmental responsibility on changing consumer behaviour – sustainable market in Slovakia. *Economics and Sociology*, *13*(3), 84-96. doi:10.14254/2071-789X.2020/13-3/6

Huang, Y. C., Backman, K. F., Backman, S. J., & Chang, L. L. (2016). Exploring the Implications of Virtual Reality Technology in Tourism Marketing: An Integrated Research Framework: The Implications of Virtual Reality Technology in Tourism Marketing. *International Journal of Tourism Research*, *18*(2), 116–128. https://doi.org/10.1002/jtr.2038

Huang, Y., Hui, S., Inman, J., & Suher, J. (2012). Capturing the "first moment of truth": Understanding point-of-purchase drivers of unplanned consideration and purchase. *JMR, Journal of Marketing Research*.

Hubert, M., & Kenning, P. (2008). A current overview of consumer neuroscience. *Journal of Consumer Behaviour*, *7*(4–5), 272–292. https://doi.org/10.1002/cb.251

Hui, S. K., Bradlow, E. T., & Fader, P. S. (2009). Testing Behavioral Hypotheses Using an Integrated Model of Grocery Store Shopping Path and Purchase Behavior. *Journal of Consumer Research*, *36*(3), 478–493. https://doi.org/10.1086/599046

Hui, S. K., Inman, J. J., Huang, Y., & Suher, J. (2013). The Effect of In-Store Travel Distance on Unplanned Spending: Applications to Mobile Promotion Strategies. *Journal of Marketing*, *77*(2), 1–16. https://doi.org/10.1509/jm.11.0436

Hunt, S. D., & Lambe, C. J. (2000). Marketing's contribution to business strategy: Market orientation, relationship marketing and resource-advantage theory. *International Journal of Management Reviews*, *2*(1), 17–43. https://doi.org/10.1111/1468-2370.00029

Huszka, P., Karácsony, P., & Juhász T. (2022). The coronavirus's effect on the decisions and habits of food purchases in Hungary. *Journal of International Studies, 15*(1), 149-167. doi:10.14254/2071-8330.2022/15-1/10

Isen, A. M. (2001). An Influence of Positive Affect on Decision Making in Complex Situations: Theoretical Issues With Practical Implications. *Journal of Consumer Psychology*, *11*(2), 75–85. https://doi.org/10.1207/S15327663JCP1102_01

Jacoby, J. (2000). Is it rational to assume consumer rationality? Some consumer psychological perspectives on rational choice theory. *Some Consumer Psychological Perspectives on Rational Choice Theory*, 00–09.

Jacoby, J., Szybillo, G. J., & Berning, C. K. (1976). Time and Consumer Behavior: An Interdisciplinary Overview. *Journal of Consumer Research*, *2*(4), 320. https://doi.org/10.1086/208644

Jung, T.-P., Makeig, S., Humphries, C., Lee, T.-W., McKeown, M. J., Iragui, V., & Sejnowski, T. J. (2000). Removing electroencephalographic artifacts by blind source separation. *Psychophysiology*, *37*(2), 163–178. https://doi.org/10.1111/1469-8986.3720163

Kacelnik, A. (2006). Meanings of rationality. In S. Hurley & M. Nudds (Eds.), *Rational Animals?* (pp. 87–106). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780198528272.003.0002

Kahneman, D. (1994). New challenges to the rationality assumption. *Journal of Institutional and Theoretical Economics (JITE)/Zeitschrift Für Die Gesamte Staatswissenschaft*, 18–36.

Kahneman, D. (2012). Pułapki myślenia. *O Myśleniu Szybkim i Wolnym*, 161.

Kahneman, D., & Thaler, R. H. (2006). Anomalies: Utility Maximization and Experienced Utility. *Journal of Economic Perspectives*, *20*(1), 221–234. https://doi.org/10.1257/089533006776526076

Kahneman, D., & Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica*, *47*(2), 263–292. https://doi.org/10.2307/1914185

Katona, G. (1953). Rational behavior and economic behavior. *Psychological Review*, *60*(5), 307–318. https://doi.org/10.1037/h0060640

Kenrick, D. T., Griskevicius, V., Neuberg, S. L., & Schaller, M. (2010). Renovating the Pyramid of Needs: Contemporary Extensions Built Upon Ancient Foundations. *Perspectives on Psychological Science*, *5*(3), 292–314. https://doi.org/10.1177/1745691610369469

Kober, S. E., Kurzmann, J., & Neuper, C. (2012). Cortical correlate of spatial presence in 2D and 3D interactive virtual reality: An EEG study. *International Journal of Psychophysiology*, *83*(3), 365–374. https://doi.org/10.1016/j.ijpsycho.2011.12.003

Kotler, P., & Keller, K. (2011). *Marketing management 14th edition*. prentice Hall.

Krasiński, Z., Piasny, J., & Szulce, H. (1984). *Ekonomika konsumpcji*. Państwowe Wydawnictwo Ekonomiczne.

Kumar, P. (2010). *Marketing of Hospitality & Tourism Services*.

Lambkin, M., Foxall, G., Van Raaij, F., & Heilbrunn, B. (2001). Zachowanie konsumenta. *Koncepcje i Badania Europejskie, PWN, Warszawa*, *25*.

Lawes, R. (2018). Science and semiotics: What's the relationship? *International Journal of Market Research*, *60*(6), 573–588. https://doi.org/10.1177/1470785318787944

Lazarou, I., Nikolopoulos, S., Petrantonakis, P. C., Kompatsiaris, I., & Tsolaki, M. (2018). EEG-based brain–computer interfaces for communication and rehabilitation of people with motor impairment: A novel approach of the 21st century. *Frontiers in Human Neuroscience*, *12*. Scopus. https://doi.org/10.3389/fnhum.2018.00014

Leibenstein, H. (1988). *Poza schematem homo oeconomicus: Nowe podstawy mikroekonomii*. Państwowe Wydawnictwo Naukowe.

Leibenstein, H. (1979a). A Branch of Economics is Missing: Micro-Micro Theory. *Journal of Economic Literature*, *17*(2), 477–502. JSTOR. Retrieved from JSTOR.

Leibenstein, H. (1979b). X-Efficiency: From Concept to Theory. *Challenge*, *22*(4), 13–22. https://doi.org/10.1080/05775132.1979.11470543

Lerner, J. S., & Keltner, D. (2000). Beyond valence: Toward a model of emotion-specific influences on judgement and choice. *Cognition & Emotion*, *14*(4), 473–493. https://doi.org/10.1080/026999300402763

Lewandowska, I. (2004). Wywiad jako technika zdobywania informacji źródłowych w badaniu historii najnowszej. *Echa Przeszłości*, *5*, 279–299.

Li, X., & Hsee, C. K. (2021). The Psychology of Marginal Utility. *Journal of Consumer Research*, *48*(1), 169–188. https://doi.org/10.1093/jcr/ucaa064

Lindenberg, S. (2001). Social Rationality versus Rational Egoism. In J. H. Turner (Ed.), *Handbook of Sociological Theory* (pp. 635–668). Springer US. https://doi.org/10.1007/0-387-36274-6_29

Mann, M. K., Liu-Thompkins, Y., Watson, G. S., & Papelis, Y. E. (2015). A Multidisciplinary Examination of 3D Virtual Shopping Environments: Effects on Consumer Perceptual and Physiological Responses. In K. Kubacki (Ed.), *Ideas in Marketing: Finding the New and Polishing the Old* (pp. 752–755). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-10951-0_277

Markin, R. J. (1979). The role of rationalization in consumer decision processes: A revisionist approach to consumer behavior. *Journal of the Academy of Marketing Science*, *7*(4), 316–334. https://doi.org/10.1007/BF02729682

Martínez-Ruiz, M. P., Blázquez-Resino, J. J., & Pino, G. (2017). Store attributes leading customer satisfaction with unplanned purchases. *The Service Industries Journal*, *37*(5–6), 277–295. https://doi.org/10.1080/02642069.2017.1315409

Maslow, A. H. (1943). A theory of human motivation. *Psychological Review*, *50*(4), 370–396. https://doi.org/10.1037/h0054346

Maslow, A. H. (1970). *Motivation and personality. New York: Harp and Row*.

Maslow, Abraham H. (1954). *„Motivation and Personalityo New York*. Harper and Brothers.

Maslow, Abrham H. (1962). *Toward a psychology of being, Princeton (D. van Nostrand Company) 1962*.

Matysik-Pejas, R., & Szafrańska, M. (2011). The rationality of consumer behavior on the food products market. *Delhi Business Review*, *12*(2), 11–19.

McMahan, A. (2003). Immersion, engagement and presence. *The Video Game Theory Reader*, *67*(S 86).

McMahan, T., Parberry, I., & Parsons, T. D. (2015). Evaluating Player Task Engagement and Arousal Using Electroencephalography. *Procedia Manufacturing*, *3*, 2303–2310. https://doi.org/10.1016/j.promfg.2015.07.376

Mishchuk, H., Štofková, J., Krol, V., Joshi, O., & Vasa, L. (2022). Social Capital Factors Fostering the Sustainable Competitiveness of Enterprises. *Sustainability*, *14*(19), 11905. https://doi.org/10.3390/su141911905

Molina, J. A. (1996). Testing for the utility maximization hypothesis of consumers using the revealed preference theory. *Journal of Consumer Studies and Home Economics*, *20*(2), 131–143. https://doi.org/10.1111/j.1470-6431.1996.tb00242.x

Morrissette, K., & Lusk, J. L. (2022). Keep Forgetting to Make a Shopping List? Don't Beat Yourself up over It! *Journal of Food Products Marketing*, *28*(2), 69–86. https://doi.org/10.1080/10454446.2022.2042758

Mowen, J. (1987). *Consumer behavior*.

Mruk, H. (2017). Zachowania konsumentów w świetle ekonomii behawioralnej. *Studia Ekonomiczne*, *312*, 82–95.

Nickerson, C. (2021). *Rational Choice Theory*. Retrieved from www.simplypsychology.org/rational-choice-theory.html

O'Shaughnessy, J. (1994). *Dlaczego ludzie kupują...* PaĹ „stwowe Wydaw. Ekonomiczne.

O'Shaughnessy, J. (2013). *Consumer behaviour: Perspectives, findings and explanations*. Houndmills, Basingstoke ; New York, NY: Palgrave Macmillan.

Over, D. (2004). Rationality and the normative/descriptive distinction. *Blackwell Handbook of Judgment and Decision Making*, 3–18.

Page, G. (2012). Scientific Realism: What 'Neuromarketing' can and can't Tell us about Consumers. *International Journal of Market Research*, *54*(2), 287–290. https://doi.org/10.2501/IJMR-54-2-287-290

Peck, R. M. (2012). Another Look at Becker's Irrational Consumer. *Theoretical Economics Letters*, *02*(03), 262–263. https://doi.org/10.4236/tel.2012.23047

Peluso, A. M. (2011). *Consumer satisfaction: Advancements in theory, modeling, and empirical findings*. Bern, Switzerland ; New York: Peter Lang.

Pluta-Olearnik, M., & Szulga, P. (2022). The Importance of Emotions in Consumer Purchase Decisions—A Neuromarketing Approach. *Marketing of Scientific and Research Organizations*, *44*(2), 87–104. https://doi.org/10.2478/minib-2022-0010

Pradeep, A. (2011). Mózg na zakupach. *Neuromarketing w Sprzedaży, Wydawnictwo Helion, Gliwice*.

Rabin, M. (2000). *Risk aversion and expected-utility theory: A calibration theorem*. Econometrica 68.

Richard, M.-O., & Laroche, M. (2011). Book Review: Neuromarketing: Exploring the Brain of the Consumer. *International Journal of Market Research*, *53*(2), 287–288. https://doi.org/10.2501/IJMR-53-2-287-288

Roesmann, K., Leehr, E. J., Böhnlein, J., Steinberg, C., Seeger, F., Schwarzmeier, H., … Junghöfer, M. (2022). Behavioral and Magnetoencephalographic Correlates of Fear Generalization Are Associated With Responses to Later Virtual Reality Exposure Therapy in Spider Phobia. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *7*(2), 221–230. Scopus. https://doi.org/10.1016/j.bpsc.2021.07.006

Romero, S., Mañanas, M. A., & Barbanoj, M. J. (2008). A comparative study of automatic techniques for ocular artifact reduction in spontaneous EEG signals based on clinical target variables: A simulation case. *Computers in Biology and Medicine*, *38*(3), 348–360. https://doi.org/10.1016/j.compbiomed.2007.12.001

Runje, B., Horvatic Novak, A., Razumic, A., Piljek, P., Strbac, B., & Orosnjak, M. (2019). Evaluation of Consumer and Producer Risk in Conformity Assessment Decisions. In B. Katalinic (Ed.), *DAAAM Proceedings* (1st ed., Vol. 1, pp. 0054–0058). DAAAM International Vienna. https://doi.org/10.2507/30th.daaam.proceedings.007

Russell, J. A., & Barrett, L. F. (1999). Core affect, prototypical emotional episodes, and other things called emotion: Dissecting the elephant. *Journal of Personality and Social Psychology*, *76*(5), 805–819. https://doi.org/10.1037/0022-3514.76.5.805

Samson, A., & Voyer, B. G. (2012). Two minds, three ways: Dual system and dual process models in consumer psychology. *AMS Review*, *2*(2–4), 48–71. https://doi.org/10.1007/s13162-012-0030-9

Schiffman, L. G., Kanuk, L. L., & Hansen, H. (2008). *Consumer behavior-An European Outlook*.

Schiffman, L. G., & Wisenblit, J. L. (2015). *Consumer Behavior 11th edition*.

Schnack, A., Wright, M. J., & Holdershaw, J. L. (2020). An exploratory investigation of shopper behaviour in an immersive virtual reality store. *Journal of Consumer Behaviour*, *19*(2), 182–195. https://doi.org/10.1002/cb.1803

Schwarz, N. (1990). *Feelings as information: Informational and motivational functions of affective states.* The Guilford Press.

Schwarz, N., Strack, F., Kommer, D., & Wagner, D. (1987). Soccer, rooms, and the quality of your life: Mood effects on judgments of satisfaction with life in general and with specific domains. *European Journal of Social Psychology*, *17*(1), 69–79. https://doi.org/10.1002/ejsp.2420170107

Seeley, E. (1992). Human needs and consumer economics: The implications of Maslow's theory of motivation for consumer expenditure patterns. *The Journal of Socio-Economics*, *21*(4), 303–324. https://doi.org/10.1016/1053-5357(92)90002-O

Senior, C., & Lee, N. (2008). A manifesto for neuromarketing science. *Journal of Consumer Behaviour*, *7*(4–5), 263–271. https://doi.org/10.1002/cb.250

Siegrist, M., Ung, C.-Y., Zank, M., Marinello, M., Kunz, A., Hartmann, C., & Menozzi, M. (2019). Consumers' food selection behaviors in three-dimensional (3D) virtual reality. *Food Research International*, *117*, 50–59. Scopus. https://doi.org/10.1016/j.foodres.2018.02.033

Simon, H. A. (1976). Model of Discovery and Topic in the Methods of Science. *Reidel Pub. Co., Dordrecht, Holland-Boston*.

Simon, H. A. (1978). Rational decision-making in business organizations. *Economic Sciences*, 343–371.

Simon, H. A. (1995). Rationality in Political Behavior. *Political Psychology*, *16*(1), 45. https://doi.org/10.2307/3791449

Słupińska, K., Duda, J., & Biercewicz, K. (2021). Planning an experiment in a virtual environment reality as a place of research on human behaviour using methods of neuroscience measurement – bibliometric analysis and methodological approach. *Procedia Computer Science*, *192*, 3123–3133. https://doi.org/10.1016/j.procs.2021.09.085

Sohn, Y. S., & Ko, M. T. (2021). The impact of planned vs. Unplanned purchases on subsequent purchase decision making in sequential buying situations. *Journal of Retailing and Consumer Services*, *59*, 102419.

Solomon, M. R., Kason-Opitek, A., Sugiero, J., & Salbut, B. (2006). *Zachowania i zwyczaje konsumentów*. Gliwice: Wydawnictwo "Helion."

Solomon, M., Russell-Bennett, R., & Previte, J. (1995). *Consumer behaviour*. Pearson Higher Education AU.

Spiggle, S. (1987). Grocery shopping lists: What do consumers write? *ACR North American Advances*.

Szwacka-Mokrzycka, J. (2015). An interdisciplinary approach to marketing. *Annals of Marketing Management & Economics*, *1*(1), 85–92.

Tan, W., Xu, Y., Liu, P., Liu, C., Li, Y., Du, Y., … Zhang, Y. (2020). A method of VR-EEG scene cognitive rehabilitation training. *Health Information Science and Systems*, *9*(1), 4. https://doi.org/10.1007/s13755-020-00132-6

Thomas, A., & Garland, R. (1993). SUPERMARKET SHOPPING LISTS: THEIR EFFECT ON CONSUMEREXPENDITURE. *International Journal of Retail & Distribution Management*, *21*(2). https://doi.org/10.1108/09590559310028040

Triandis, H. C. (1979). *Values, attitudes, and interpersonal behavior.* 195–259. University of Nebraska Press.

Tromp, J., Peeters, D., Meyer, A. S., & Hagoort, P. (2018). The combined use of virtual reality and EEG to study language processing in naturalistic environments. *Behavior Research Methods*, *50*(2), 862–869. https://doi.org/10.3758/s13428-017-0911-9

Tyszka, T., & Zaleśkiewicz, T. (2001). *Racjonalność decyzji: Pewność i ryzyko*. Polskie Wydaw. Ekonomiczne.

Von Neumann, J., & Morgenstern, O. (1947). *Theory of games and economic behavior, 2nd rev*.

Wahba, M. A., & Bridwell, L. G. (1976). Maslow reconsidered: A review of research on the need hierarchy theory. *Organizational Behavior and Human Performance*, *15*(2), 212–240. https://doi.org/10.1016/0030-5073(76)90038-6

Wang, J., Shen, M., & Gao, Z. (2018). Research on the Irrational Behavior of Consumers' Safe Consumption and Its Influencing Factors. *International Journal of Environmental Research and Public Health*, *15*(12), 2764. https://doi.org/10.3390/ijerph15122764

Wilkinson, N., & Klaes, M. (2018). *An introduction to behavioral economics* (Third edition). London: Red Globe Press.

Włodarczyk, K. (2013). *Rynkowe zachowania polskich konsumentów w dobie globalizacji konsumpcji*. Wydawnictwo Adam Marszałek.

Wohlgenannt, I., Simons, A., & Stieglitz, S. (2020). Virtual Reality. *Business & Information Systems Engineering*, *62*(5), 455–461. https://doi.org/10.1007/s12599-020-00658-9

Xiao, J. J., Ford, M. W., & Kim, J. (2011). Consumer Financial Behavior: An Interdisciplinary Review of Selected Theories and Research: CONSUMER FINANCIAL BEHAVIOR. *Family and Consumer Sciences Research Journal*, *39*(4), 399–414. https://doi.org/10.1111/j.1552-3934.2011.02078.x

Zalega, T. (2012). Rational And Methods Of Research Into Consumer Market Behaviour. *Equilibrium*, *7*(4), 77–99. https://doi.org/10.12775/EQUIL.2012.028

Zalega, T. (2014). Consumer and Consumer Behaviour in the Neoclassical and Behavioural Economic Approach. *Konsumpcja i Rozwój*, (4(9)), 64–79.

Zaleśkiewicz, T. (2015). *Psychologia ekonomiczna*. Wydawnictwo Naukowe PWN Warszawa.

Zhao, J., Xue, F., Khan, S., & Khatib, S. F. A. (2021). Consumer behaviour analysis for business development. *Aggression and Violent Behavior*, 101591. https://doi.org/10.1016/j.avb.2021.101591

Zhao, Q., Zhang, L., & Cichocki, A. (2009). EEG-based asynchronous BCI control of a car in 3D virtual reality environments. *Chinese Science Bulletin*, *54*(1), 78–87. https://doi.org/10.1007/s11434-008-0547-3

Zimbardo, P., & Gerring, R. (2017). Psychologia i życie. *Materska M. Tł. Czerniawska E. i in., Wyd. Nauk. PWN, Warszawa*.

Authors' Note

All correspondence should be addressed to:
Patryk Wlekły
Inistitute of Management
University of Szczecin
Poland
patryk.wlekly@usz.edu.pl

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

Human TECHNOLOGY

ISSN: 1795-6889

https://ht.csr-pub.eu Volume 18(3), December 2022, 297-315

IS TECHNOLOGY GENDER NEUTRAL? A SYSTEMATIC LITERATURE REVIEW ON GENDER STEREOTYPES ATTACHED TO ARTIFICIAL INTELLIGENCE

Miruna-Valeria Crăiuț
Department of Communication, Public Relations, and Advertising
Faculty of Political, Administrative, and Communication Sciences
Babeș-Bolyai University, Cluj-Napoca
Romania

Ioana Iancu
Department of Communication, Public Relations, and Advertising
Faculty of Political, Administrative, and Communication Sciences
Babeș-Bolyai University, Cluj-Napoca,
Romania

Abstract: Artificial Intelligence implies computer systems capable of mimicking human-like intelligence and competencies. In the nowadays society it is an exciting topic, thus, technology's gender features and roles are of great interest as well. As the literature is still scarce and inconsistent, the present paper aims to develop a systematic literature review on gender stereotypes attached to technology (virtual assistants and robots). The main goals are to emphasize the labels given to technology from a gender perspective, the perceived competencies of the gendered technology, the most relevant variables responsible for the way gender issues are perceived in connection with technology, and the proposed solutions for diminishing the technology gender stereotypes. Forty-five scientific papers have been selected and analyzed. Findings suggest that the most intelligent technologies are designed as females, male-gendered technology performs better in task-solving, and users' age and technology's visual representation are important variables in perception.

Keywords: *Gender stereotypes; Artificial intelligence; Virtual assistants; Robots; Systematic literature review.*

DOI: https://doi.org/10.14254/1795-6889.2022.18-3.6

INTRODUCTION

Stereotypes imply placing a piece of information into a certain category based on the type of data it has stored (Brahnam & De Angeli, 2012). While gender stereotypes are believed to affect the way individuals perceive and interpret information about themselves, they also shape the expectations of others (Ellemers, 2018). Gender stereotypes are both descriptive, meaning that they are formed around a characteristic a man or a woman possesses, and prescriptive, which reflects the social perception of what a person should be according to their gender (Brahnam & De Angeli, 2012). Stereotypes are explained through social role theory, which infers that once individuals form strong gender beliefs, they associate these beliefs with social roles that are specific to men or women (Hentschel et al., 2019; Guo et. al., 2020). These presumptions manifest both in home environment and at work (Hentschel et al., 2019; Guo et. al., 2020). Social roles refer to expectations regarding behavior (Guo et. al., 2020). They influence the perceptions concerning the adequate occupation for men and women (Guo et. al., 2020). Unfortunately, in social interactions this aspect is usually harmful and can lead to several biased preconceptions that are not in accordance with reality. Gender stereotypes are irrational beliefs related to the gender of the individual, suggesting that women and men are behaving in a specific manner because of their gender (Brahnam & De Angeli, 2012). Stereotypes can induce incorrect assessments that can bias decisions or expectations of performance (Hentschel et al., 2018; Hentschel et al., 2019). These biases are typical also for employers in their managerial decisions regarding female employees (Samoliuk et al., 2022) which, in their turn, encourage women to seek new possibilities with higher-paid positions (Lauzadyte-Tutliene & Mikuciauskaite, 2022). No doubt, some gender-related issues can influence the organizational outcomes, especially in services (Shava, 2021). These cognitions are deeply entrenched in the individual's mind and are very difficult to change (Brahnam & De Angeli, 2012).

Stereotypes are so powerful that not only are they generated in the human-to-human interactions, they are also applied to non-human entities (Brahnam & De Angeli, 2012). The relation between technology and gender stereotypes started to become a subject of interest in the 1990's, when the presence of stereotypes was identified in interactions with computers (Nass, Moon, & Green, 1997).

Artificial intelligence (AI) is a relatively new technology that had its debut in the 1950' and rapidly evolved into the most fascinating topic of interest among all new technologies today (Helm et al., 2020). AI can be defined as the ability of a machine to simulate human intelligence. This process often consists of a progressive learning experience in which an intelligent agent is assimilating information in the same manner an individual does (Zhang & Lu, 2021). As a research topic, AI is applied in several fields of activities and disciplines and presents different approaches (Zhang & Lu, 2021). AI is divided in multiple typologies consisting into analytical, human-inspired or humanized versions (Haenlein & Kaplan, 2019). Its level of development and thus, intelligence, also varies from basic intelligence performance to super intelligence (Haenlein & Kaplan, 2019).

The emergence of AI creates new research perspectives for the study of stereotypes, especially since the link between gender perceptions on technology is contradictory. On one hand, the literature emphasizes that gender stereotypes are problematic, and they affect interactions with technology (Thellman et al., 2018), potentially threatening real-life

interactions. Studies are focusing on the lack of perceived competence in female virtual agents (Ahn, Kim, & Sung, 2022), as well as on associations of virtual assistants with specific gender roles such as nurse (Tay, Jung, & Park, 2014) or housekeeper (Eyssel & Hegel, 2012). They can also be sexually abused and denigrated while interacting with individuals, which is worrying (Veletsianos, Scharber, & Doering, 2008). On the other hand, in many instances, female virtual assistants are perceived as being more trustworthy than male agents and they are preferred in performing some specific activities (Pfeuffer et al., 2019; Guo et al., 2020; Borau et al., 2021).

In this context, the present paper aims to offer a systematic literature review on the way gender stereotypes are attached to AI in general and to virtual assistants and robots in particular. To our knowledge, a theoretical review that aims to systematically cover the knowledge and understandings on the way technology triggers gender labels has not been done before. The proposed research questions are the following:

RQ1. Which are the labels given to technology from a gender perspective?

RQ2. How are the gender stereotypes affecting the perceived competence of virtual assistants and robots?

RQ3. What variables are responsible for perceived gender stereotypes on AI?

RQ4. What solutions for diminishing the technology gender stereotypes are proposed in the literature?

As the interaction between humans and technology is increasing in all domains and the phenomenon of gender stereotyping is more and more present in daily life, the relevance of the study is twofold. First, at the scientific level, emphasizing the most frequent causes for gender stereotyping and their effect on human-machine interaction, the paper fills in the literature gap and offers a practical basis for future studies. Second, at the business level, the review can serve as a basis for further technical decisions. By understanding the communication patterns of individuals when interacting with technology, engineers and technology designers can help diminish the gender stereotypes present in human-computer interaction.

The existing results are still to be debated and explored. First, the literature has not yet reached an agreement on which intelligent technologies are more likely to be the object of stereotyping, virtual assistants, chatbots, robots, or computers. At the same time, the age and race of the AI can influence the overall perception. Second, existing studies emphasize a general interest in user gender, trying to observe if males or females are more likely to exhibit stereotypical opinions on technology. Moreover, perceived trust, warmth and compassion are paramount variables addressed.

Technology and Gender Stereotypes

Anthropomorphization can be described as the tendency of individuals to attribute human characteristics to animals or objects (Ahn, Kim, & Sung, 2022). In the technological context, the most common scientific base for machine anthropomorphization refers to Computers as Social Actors paradigm (CASA). The theory has been developed by Clifford Nass and explains the communication process between humans and technology (Nass & Moon, 2000). It suggests that individuals act in relation with technology in the same manner as they do with other humans. Thus, computers become social actors because individuals retain the same patterns of interpersonal communication while interacting with them (Guzman, Lewis, 2019).

This paradigm is explored throughout most of the studies referring to virtual agents or artificial assistants. Many technologies are created to follow several human traits for a higher level of accessibility to the public. Literature suggests that individuals prefer interacting with humanized entities and have different preferences for agent personality and traits (Cercas Curry, Robertson, & Riser, 2020).

Studies have shown that stereotypes apply to technology and the evaluation of different cues impact several perceived competence items. Usually, female-gendered technology is perceived as having lower levels of trustworthiness and intelligence, compared to the technology that embodies a man, but higher levels of warmth and empathy (Haake & Gulz, 2008)

It is emphasized that stereotypes are more likely to occur when technology is used in domains that are specific for one of the genders, rather than in gender neutral ones. Thus, when technology embodies a woman, individuals perceive its competence higher in domains that are typical for women, compared to technical or other occupations that are labeled as being specific for men. Similarly, technology that embodies men is perceived as more competent when performing tasks of its gender. Gender stereotypes are less likely to occur in technology where the performed task is gender neutral, suggesting that individuals are not consciously discriminating gendered technology, but they unconsciously apply the stereotypes in the virtual environment (McDonnell & Baxter, 2019; Dufour & Ehrwein Nihan, 2016). Individuals are usually inclined to prefer female-gender technology. This preference is due to the perceived warmth and emotions. Studies on AI particularly mention that humans are inclined to favour technology that is more humanized, and they underline that female technology is perceived as being more humanlike than male one. As technology lacks emotions and warmth in particular, this is assumed to be the rationale behind human preference for female-gendered technology (Borau, Otterbring, Laporte, & Fosso Wamba, 2021).

Even if individuals prefer female-gendered technology, they perceive it as less competent compared to male technical embodiment (Ernst & Herm-Stapelberg, 2020; Lee, 2003; Ahn, Kim, & Sung, 2022). Previous studies mention that a male computer voice is perceived as more valid than a female one and thus, it is suggested that its competence level, as well as effectiveness, is higher due to this bias. Moreover, dominant traits are preferable for male-gendered technology rather than female , which have high implications to the way society position itself regarding problematic gender roles (Ahn, Kim, & Sung, 2022).

As gender affects the way agents are perceived (Lee, 2003), both women and men are more focused in solving correctly different tasks for the opposite virtual agent gender (Lee, 2003; Reich-Stiebert & Eyssel, 2017). Men are more likely to be persuaded by female agents and find them trustworthy (Lee, 2003), while females could perceive a male agent in a similar way to the female one (Guo et al., 2020). The level of stereotyping is also age correlated. Individuals' age and gender have a major influence on the way they perceive gendered technology (Watkins & Pak, 2020). Older individuals are perceiving male and female gendered agents differently compared to younger ones, as they have stronger stereotypical believes towards women (Watkins & Pak, 2020; Ladwig & Ferstl, 2018). Therefore, female agents are perceived as having lower competence in comparison with their male counterparts (Watkins & Pak, 2020; Ladwig & Ferstl, 2018). The degree on which the stereotypes are reinforced in communication with different types of technology depends on situational contexts, such as tasks the robots are required to perform or the environment in which is applied (Nomura & Kinoshita, 2015).

Artificial Intelligence and Gender Stereotypes

The most recent research approaches on technology and gender are oriented towards artificial intelligence (e.g., robots, virtual assistants). AI is defined as a computer-based system able to reproduce human-like characteristics, as intelligence and capabilities, as closely as possible (Townsend & Hunt, 2019; Woinaroschy, 2020). AI is able to generate images, recognize and understand language, speech, and visual items, make decisions and actively interact with individuals (Adams, 2019; Dornis, 2020). By using natural language processing, machine learning, automated reasoning, computer vision, and robotics, AI has become a significant part of our daily normal (e.g., GPS navigation, personal assistants, chatbots etc.) (Townsend & Hunt, 2019; Mezei, 2020).

Although AI is born as a gender-neutral entity, the literature mentions the impaired judgment of the individuals regarding a gendered AI, which impact the interaction between those two. Individuals unconsciously apply the categorization process which, in this case, is represented by the process of gendering objects (Bernotat, Eyssel, & Sachse, 2019). Even if a type of technology has no gendered cues, humans will attribute a gender to it. Therefore, robots are more likely to be perceived as male rather than female., yet virtual assistants are more likely to be perceived as female (Bernotat, Eyssel, & Sachse, 2019).

This perspective has been also analyzed in the interaction between children and robots. One experiment analyzes the possibility of inducing counter stereotyping roles in children by manipulating robots using the Wizard-of-Oz Method (Song-Nichols & Young, 2020; Vega et al., 2019) to measure whether this could diminish stereotypes in individuals. The findings emphasize that children further apply the believes about robot occupations to real-life situations, suggesting that they use robots as models which can either reinforce or suppress gender stereotypes in real life (Song-Nichols & Young, 2020). Some articles, yet few, mention no presence of gender stereotypes in technology performance in either male or female agents, especially in gender-neutral tasks such as pedagogy (Pfeifer & Lugrin, 2018). The most promising gender-neutral situations are the ones in which a robot's age is manipulated. Thus, child-like designed robots are more likely to not be perceived in the gender binary and avoid stereotypical situation when communicating with humans (Ladwig & Ferstl, 2018).

Since virtual assistants are social actors, gender stereotypes are not only affecting the perceived task competence, but the overall human-machine interaction and communication processes. This presumption is supported by Media Equation Theory which implies that the processes behind interpersonal communication apply to human-machine interaction and affect individual's social judgements (Dufour & Ehrwein Nihan, 2016).

Findings on artificial intelligence suggest that the presence of gender stereotypes is balanced (Nag & Yalçın, 2020). While some studies emphasize the presence of gender stereotypes (McDonnell & Baxter, 2019), others are presenting opposite results (Nag & Yalçın, 2020). Surprisingly, more articles present female virtual assistants as more competent than male virtual assistants. The literature suggests that this is probably because social agents are more likely to be designed as female-gendered (Borau et al., 2021; Ferreira da Costa, 2018), whereas other types of technology, such as robots, are more often designed to be male-gendered (Ferrando, 2014; Bernotat, Eyssel, & Sachse, 2019).

Several artificial assistants are anthropomorphised as females due to individual's perceptions on female traits (Ernst & Herm-Stapelberg, 2020). As humans tend to prefer

human-like machines, female features include more emotional human-like attributes such as warmth, friendliness, traits that increase their general acceptance (Borau et al., 2021). Contrary, male agents are more likely to be perceived as a threat (Otterbacher & Talias, 2017).

Many female agents are designed to have warm and submissive traits (Cercas Curry et al., 2020). Moreover, in many cases they depict different level of sexualization (Gustavsson, 2005). While the literature mentions their effectiveness on persuading men, what is worrying is that female virtual agents are the most likely to become objects of aggression and sexual abuse (Brahnam & De Angeli, 2012). While this is not affecting the technical tool itself, the violent behavior of the individuals regarding the submissive assistant is worrying (Veletsianos, Scharber & Doering, 2008). This could not only further promote gender stereotypes, but even normalize the objectification of women.

Likewise, agents' visual representation is often responsible for inducing different stereotypes that impairs the judgement regarding the effectiveness of the specific technology (Bernotat, Eyssel & Sachse, 2019). Since women are associated with more humanlike traits, many companies intentionally feminize technological assistants to increase their acceptance (Borau et al., 2021; Furqon et al., 2021). Yet, sometimes designing female agents help inducing stereotypical traits. While male agents are usually designed to look normal, female ones are exhibiting different attractive actions such as waving, winking, smiling to their users (Gustavsson, 2005). Increased visual attractiveness and sexual elements in agents' design may help in creating higher acceptance towards male-gendered agents (Guo et al., 2020), yet the result led to stereotyping and abuse (Veletsianos, Scharber & Doering, 2008).

Often in gender-neutral tasks, a lower level of stereotyping for both male or female virtual assistants is noticed (McDonnell & Baxter, 2019). Other factors such as the age of the virtual assistant may affect perception on its capability (Pak, McLaughlin, & Bass, 2014). In this way, older female agents are treated more harshly and are more stereotyped by the users than younger female assistants (Pak, McLaughlin, & Bass, 2014).

METHODOLOGY

To have a better understanding on how gender stereotypes are attached to technology, a systematic literature review is developed. With the aim of gaining a general view of the topic, a significant number of studies were selected from the current literature. In this respect, PRISMA (Preferred Items for Systematic Reviews and Meta-Analysis) method was applied as a provision for choosing the most appropriate papers (Bereczki & Kárpáti, 2018). The method consists of the following steps: (1) analysis of the potential keywords; (2) multiple data-base database searches using the keywords; (3) papers' selection after content analysis; (4) information that follows the criteria set extraction; (5) analysis and evaluation of the findings. Figure 1 summarizes the selection process.

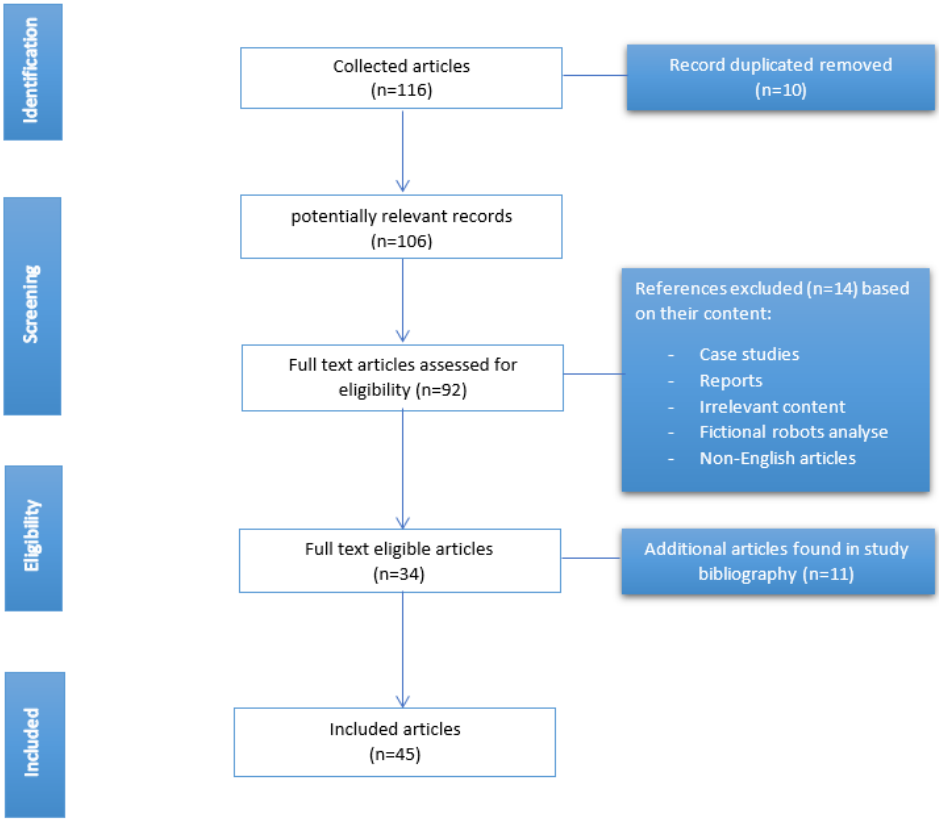

Figure 1. PRISMA flow chart for articles selection

Selection Criteria

The following items have been taken into consideration in the selection process: (1) topic - studies that follow the presence and the effects of gender stereotypes on technology (virtual assistants, robots, machines etc.); (2) aim of the study; (3) language (English); (4) full text access to the article.

Regarding the exclusion criteria, articles on the following topics have been omitted from the analysis: gender stereotypes that apply to individuals that interact with technology, gender studies that apply on technology which are not focused on stereotyping, articles that are oriented towards gender design of robots/virtual assistants and not on the presence of gender stereotypes, or articles that focus on other type of technology stereotyping (age, race) and that are excluding gender.

Search Strategy

Since the topic is relatively recent and few research approaches are present in literature, the studies have been selected without a time criterion. Thus, in order to have a longitudinal overview, the articles have been searched using relevant keywords in major databases, such as Oxford Academic, MDPI, ProQuest, ERIH Plus, Science Direct, ACM Digital Library, NCBI, ACL Anthology, or Research Gate. The used keywords are the following: gender stereotypes

and technology, gender stereotypes and artificial intelligence, gender stereotypes and robots. Moreover, similar articles suggested by the journal websites have been considered during the research, as well as the relevant studies found in the bibliographies of the selected articles. Both scientific articles published in journals and proceedings' papers have been used.

After evaluating the selected databases, a number of *N*=45 studies that respect the imposed criteria have been extracted and analyzed. Several studies have been excluded due to lack of access or incomplete published parts. Table 1 presents all the publications included in the analysis.

Table 1. The sample of articles included in the analysis

No.	Journal / Proceedings	Number of articles	Source
1	Cyberpsychology, Behavior, and Social Networking	1	Kim et al., 2019
2	Interacting with Computers	3	Brahnam & De Angeli, 2012; McDonnell & Baxter, 2019; Veletsianos, Scharber, & Doering, 2008
3	Journal of Science and Technology of the Arts	1	Ferreira da Costa, 2018
4	Gender, Work and Organization	1	Gustavsson, 2005
5	European Journal of Futures Research	1	Ferrando, 2014
6	International Journal of Social Robotics	5	Law, Chita-Tegmark, & Scheutz, 2020; Kuchenbrandt et al., 2014; Bernotat, Eyssel, & Sachse, 2019; Weßel, Ellerich-Groppe & Schweda, 2021; Carpenter et al., 2009
7	Educational Technology & Society	1	Haake & Gulz, 2008
8	Computers in Human Behavior	2	Tay, Jung, & Park, 2014; Chang, Lu, & Yang, 2018
9	Journal of Applied Social Psychology	2	Eyssel & Hegel, 2012; Nass, Moon, & Green, 1997
10	Journal of Business Research	1	Ahn, Kim, & Sung, 2022
11	Social Sciences	1	Dufour & Nihan, 2016
12	Psychology & Marketing	1	Borau et al., 2021
13	Ergonomics	1	Pak, McLaughlin, & Bass, 2014
14	Frontiers in Robotics and AI	1	Ghazali et al., 2018
15	Cognitive Development	1	Okanda & Taniguchi, 2021
16	International Journal of Human-Computer Studies	1	Lee, 200
17	Proceedings of the Second Workshop on Gender Bias in Natural Language Processing	1	Cercas Curry, Robertson, & Rieser, 2020
18	Proceedings of the 20th ACM International Conference on Intelligent Virtual Agents	1	Nag & Yalçın, 2020
19	IOP Conference Series. Materials Science and Engineering; Bristol	1	Furqon et al., 2021
20	International Conference on Information Systems (ICIS) 2020	1	Guo, Yin, Liu, Xu, 2020
21	14th ACM/IEEE International Conference on Human-Robot Interaction (HRI)	1	Chita-Tegmark, Lohani, & Scheutz, 2019
22	Proceedings of Gender and IT Appropriation. Science and Practice on Dialogue - Forum for Interdisciplinary Exchange	1	Want & Young, 2014
23	CogSci 2020 Conference, Toronto	1	Song-Nichols & Yong, 2020

24	International Conference on Artificial Intelligence in Education	1	Pfeifer & Lugrin, 2018
25	Proceedings of the 10th international conference on Engineering Psychology and Cognitive Ergonomics: understanding human cognition	1	Tay et al., 2013
26	Ergonomics	1	Pak, McLaughlin, & Bass, 2014
27	13th International Conference on Ubiquitous Computing and Ambient Intelligence UCAmI 2019	1	Vega, Ramírez-Benavides, Guerrero, and López, 2019
28	Proceedings of the Human Factors and Ergonomics Society Annual Meeting	1	Watkins & Pak, 2020
29	Proceedings of the Annual Hawaii International Conference on System Sciences	1	Ernst & Herm-Stapelberg, 2020
30	TRAITS Workshop Proceedings (arXiv:2103.12679) held in conjunction with Companion of the 2021 ACM/IEEE International Conference on Human-Robot Interaction, March 2021	1	Neuteboom & de Graaf, 2021
31	Proceedings of the 4th Conference on Gender & IT - GenderIT '18	1	Ladwig & Ferstl, 2018
32	Proceedings of the 18th International Conference on Intelligent Virtual Agents	1	Thellman et al., 2018
33	International Conference on Information Systems (ICIS) 2019 Conference	1	Pfeuffer & Toutaoui, 2019
34	RO-MAN 2021 Workshop on Gendering Robots: Ongoing (Re)configurations of Gender in Robotics (GenR)At: Virtual conference	1	Perugia, 2021
35	International Conference on Culture and Computing, 2015	1	Nomura & Kinoshita, 2015
36	Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction	2	Otterbacher & Talias, 2017; Reich-Stiebert & Eyssel, 2017

DATA ANALYSIS

For the data analysis, a set of items from each publication has been considered: publishing data, author, title, journal, volume and number, topic, research questions, aim of the study, key concepts, conceptual framework and the relevant literature, method, hypothesis, measurements, sample, independent variables, dependent variables, results, hypotheses (validated/invalidated), discussion/limitations, and research perspectives.

Most of the selected articles are published in international journals (60%, n=27), while the rest (40%, n=18) are published in conference proceedings. The thematic is multidisciplinary. The analyzed articles are part of several fields such as: social sciences, technology, pedagogy, arts, marketing, business, ergonomics, linguistics and organization. The methodological designs are either quantitative, qualitative, or mixt. There is a prevalence for quantitative data analysis. More than half of the articles (68,88%, n=28) approach an experimental perspective.

The majority of the articles are based on Computers as Social Actors Theory (CASA) and explain the individual's inclination to apply gender stereotypes on different technologies through the anthropomorphizing process. Several articles describe the stereotypes as concept,

as well as gender stereotypes and offer different definitions for these psychological processes. Gender stereotypes have been associated with the age and sex of the individual as well as with personality traits (Chang, Lu, & Yang, 2018) or race (Brahnam & De Angeli, 2012). Likewise, the main independent variables that can induce gender stereotypes in human-computer interaction are: attitudes towards the assistant or agent (Borau et al., 2021; Wang & Young, 2014; Ghazali et al., 2018) the type of task performed by the agent (Dufour & Ehrwein Nihan, 2016), emotional intelligence (Law, Chita-Tegmark, & Scheutz, 2020; Chita-Tegmark, Lohani, & Scheutz, 2019), perceived competence (Kuchenbrandt et al., 2014; Eyssel & Hegel, 2012; Vega, et al., 2019; Reich-Stiebert & Eyssel, 2017), and perceived warmth (Kim et al., 2019; Nass, Moon, & Green, 1997; Bisconti & Perugia, 2021; Ahn, Kim, & Sung, 2022). Thus, while female-gendered technology is mainly associated with warmth (Neuteboom & de Graaf, 2021), communal traits (Eyssel & Hegel, 2012), and affective trust (Bernotat, Eyssel, & Sachse, 2019), male-gendered technology is associated with competence (Pfeuffer et al., 2019), agentic traits (Eyssel & Hegel, 2012), and cognitive trust (Bernotat, Eyssel & Sachse, 2019).

The effects of gender stereotypes on technology are mainly associated with different performing attributes (Vega et al., 2019). If the level of perceived competence is low, the individuals are less likely to interact with and accept a certain type of technology or to perpetuate the stereotypes in real life interactions (Kuchenbrandt et al., 2014).

RESULTS

The results of the systematic literature review are presented in a dichotomous manner. First, the gender stereotypes are discussed in studies regarding virtual assistants. Second, the same topic is approached in the context of robots.

Gender Stereotypes on Virtual Assistants

Stereotypes are cognitive processes that help individuals identify problematic issues regarding a person. This is the reason why it is difficult to reshape them to avoid their negative effect. However, technology can help shape new generations that could become less oriented towards strong stereotypes that lead to discrimination (Haake & Gulz, 2008). Gender stereotypes are highly frequent while communicating with conversational agents or virtual assistants. It is suggested that this issue affects the human-machine relation more than the effectiveness of transmitting a certain information (Cercas Curry et al., 2020).

Artificial intelligence agents are perceived differently depending on variables and situational contexts (e.g., competences, age, design). The present studies are divided into two groups regarding perceived competence. However, there is a very low difference between the perceptions regarding male assistants and the ones that refer to female assistants. While more than half of the studies (55,56%) suggest that male assistants are perceived as performing better than female, the rest of the publications (44,44%) present better perceived opinions for female assistants. Gender stereotypes are more often applied on technology where the gender is not actually matching a stereotypical occupation. Thus, technology that embodies women who perform a male-specific task causes more stereotypical perceptions in an individual's minds than one that performs a female-specific role (McDonnell & Baxter, 2019).

Some studies are presenting surprising results on virtual assistants' competences. In some instances, female-gendered technology is more efficient than male-gendered one, which suggests they possess likeable attributes for individuals interacting with them. In the current situation male are being more likely to be persuaded by a female virtual agent, while oppositely, the male agents are having a negative impact on real women (Guo et al., 2020).

Another study suggests that female-gendered technology, specifically conversational agents, are more likely to be perceived as competent than men in male-specific domains. The identified results assumed that female agents are perceived as being competent in cooperative tasks, independently of the area of activity. Thus, even if the domain in which they perform is specific for men, their competence will be perceived as higher if the action implies cooperation (Pfeuffer, 2019).

Virtual assistants are also evaluated in relation with age. This variable generates worse ratings for the femalegendered virtual assistants in older adults (Pak, McLaughlin, & Bass, 2014). In one of the analyzed studies, this difference is observed through individual's attitudes towards virtual assistant recommendations. While the level of trust on utilitarian products recommendations was higher for male assistants, for the female assistants the hedonic products raised a greater amount of trust (Ahn, Kim, & Sung, 2022).

Another problematic approach refers to the level of which the stereotypes are reinforced in virtual assistants by design. It is an issue that many artificial intelligence tools embody females and manifest stereotypical behaviors while they are programmed by men (Gustavsson, 2005). Virtual assistants are often built to denote feminine traits such as caregiving or showing interest despite their task (Ferreira da Costa, 2018). Human attributes are associated with emotions and warmth. The literature suggests that this is a possible cause of consumer preference for female artificial intelligence assistants (Borau, Otterbring, Laporte, & Fosso Wamba, 2021).

Research similarly indicates that female-gendered systems are perceived as more trustworthy when the reliability is low, compared to men. This implies that a male-gendered voice assistant is seen trustworthy only when its functionality is high (Watkins & Pak, 2020). In this way, the presence of gender stereotypes is confirmed since women are more likely to be perceived as trustworthy due to the difference in social power.

Diminishing stereotypes on technology is crucial as individuals tend to exhibit abusive behavior on technology and further manifest aggressive behavior on virtual beings. This situation can potentially worsen their perceptions regarding one of the genders in the real life (Veletsianos, Scharber, & Doering, 2008).

Gender Stereotypes on Robots

Many studies mention that individuals apply the categorization process to inanimate objects and in relation with technology. Individuals have difficulty interacting with genderless entities. If the gender of a machine is not pre-defined, humans will attribute one for it subconsciously. Therefore, it is still not likely to erase stereotypes by designing genderless robots yet (Ladwig & Ferstl, 2018). While they are rarely considered to be a female in the absence of specific cues, robots or cyborgs are usually associated with male gender or with being gender neutral (Ferrando, 2014). The differences in a robot's gender perception may vary in respect to competence, social roles attributed to humans in different contexts, and emotional traits.

Studies on technology and education claim that children start to have strong stereotypes at the age of 5. Yet, they are highly prone to have flexible perceptions regarding stereotypes during and before that age. Thus, children are more likely to have stereotypical opinions when exposed to traditional gender roles and non-stereotypical when stimulated to have counter-specific believes (Song-Nichols & Young, 2020). Children older than 5 years old attribute different objects with a specific gender. In this way, they consider that a car is a male and a flower is a woman. Moreover, young boys are more likely to see objects as being male-gendered.Children younger than 5 have a more flexible assignment of gender to objects , which suggests than gender stereotypes could be diminished in working with young children (Okanda & Taniguchi, 2021).

Most of the studies that focuse on analyzing perceived competence on robots present no relation between competence and robot's gender (Nag and Yalçın, 2020; Pfeifer & Lugrin, 2018). Interestingly, the relation between gender and competence suggest that female robots are more frequently perceived, in the current studies, as being more competent than male robots (Vega et al., 2019; Guo et al., 2020). The level of pleasure while interacting with technology is presumed to be related to matching gender-stereotypical traits. Robots are identified with male traits through the process of categorization and they could be stereotypically judged from this gender when performing a task (Bernotat, Eyssel, & Sachse, 2019). Technology designed with counter-stereotypical approaches and occupations specific for the opposite gender decreases the affective evaluations of the individuals communicating with them (Tay, Jung, & Park, 2014). Individuals have higher trust on gender-matching roles. One study suggests that when a computer is generating answers matching their imposed gender, individuals are more likely to change their initial answers on the topic and trust the robot's recommendation (Lee, 2003).

Visual representation is one of the most relevant factors in generating stereotypes regarding the gender role of computers (Lee, 2003). Certain physical traits determine individuals to attribute a gender to technology. One of the analyzed articles suggests that participants are more likely to choose a task related to mathematics to male robots, while they have no specific preference for the female task (Eyssel & Heagel, 2012). Overall, the literature suggests that performing the task successfully is the key to decrease stereotypical believes on robot gender (Neuteboom & de Graaf, 2021).

In some studies, female robots are suggested to be more persuasive than males (Ghazali et. al, 2018). Female robots are rated higher in performance and preferred during interactions due to individual's perceptions of women as responsible and reasonable beings. However, there was no significant difference between the two genders (Vega et. al., 2019). Other studies present results in which female-gendered robots outperform male ones, both in sympathy perception and in intelligence (Vega et al., 2019). Additionally, women traits are perceived as more likeable and thus they have a higher degree of acceptance (Chang, Lu, & Yang, 2018). While technology that embody a female is preferred in general by both human genders, robots of opposite gender are rated as more credible and trustworthy. These results are probably related to real life perceptions regarding the opposite gender (Nomura & Kinoshita, 2015).

Individuals believe that certain gender stereotypes are genuine. Thus, they have strong assumptions when they receive evaluations from a computer. Evaluations from men are considered more valid than those coming from women. Similarly, the level of dominance is more acceptable in male-gendered computers than in female ones. These assumptions are

outlined by individuals even if they are aware that a computer is just a tool, yet their perception is biased and they are transferring real-life attitudes on technology (Nass, Moon, & Green, 1997).

Gender stereotypes are activated on situational circumstances. A robot that provides help with home chores is more likely to be associated with a woman, while security tasks are associated with man (Tay et al., 2013). Social robots are expected to act in a feminine manner and be affectionate, loyal and sensitive (Chang, Lu, & Yang, 2018). Female-gendered technology is preferred in home-use (Carpenter et al., 2009), which is further emphasizing that gender roles are still prevalent in individuals' minds. The gender of a robot is usually not affecting neutral occupations such as teaching, since it is not activating strong stereotypes (Pfeifer & Lugrin, 2018).

Emotional intelligence is a very strong factor for working with robots and technology. Previous research confirms its importance as it affects the level of perceived trustworthiness, performance and social abilities. Moreover, this variable affects gender stereotypes as people transfer their expectations in the robot and relate it to its gender. This creates a cognitive bias in working with different artificial agents (Law, Chita-Tegmark, & Scheutz, 2020). Oppositely, in some studies, robot gender is thought to be independent from emotional intelligence and trust (Law, Chita-Tegmark, & Scheutz, 2020). Gender cues are inducing different stereotypes related to emotional intelligence. In this way, female-gendered robots are perceived as having more emotional intelligence then a male robot, even if the gender manipulation is not actually influencing this attribute (Chita-Tegmark, Lohani, & Scheutz, 2019).

The reason for designing a specific gender for technology should be in relation with its effect and usage. Therefore, it is relevant to know how different situational contexts and variables influence the perceptions on gender stereotypical tasks and what are the most effective methods in which individuals can benefit from gendered technology design (Powers et al., 2005). Other studies also mention the difficulty of implementing gender-neutral robots in human-machine interaction. Thus, other measures should be considered to solve gender stereotypes issues (Bisconti & Perugia, 2021). It is suggested that one way to diminish perceived stereotypes during human-machine interaction is to provide a clear description of the characterizing of that robot. When individuals know exactly what type of tasks a robot should perform, they are less likely to make judgements based on their gender role (Dufour & Ehrwein Nihan, 2016).

DISCUSSIONS AND CONCLUSION

Gender stereotypes are still prevailing in society nowadays. Moreover, as technology and AI in particular are increasingly present in nowadays lives, a closer look on how stereotypes are transferred from human-to-human to human-to-machine interaction becomes of paramount interest. Being a rather debatable, incomplete and scarcely understood perspective, the relation between gender and technology calls for a comprehensive overview. The present paper has developed a systematic literature review on studies approaching gender stereotypes attached to both virtual assistants and robots.

The first research question (RQ1) aims to better understand how technology is being labeled from a gender perspective. The results outline that most of the chatbots and artificial

intelligence assistants are designed to be female (Cercas Curry, Robertson, & Rieser, 2020). Since females are perceived as warmer and less dominant, their level of likeability increases in the user's mind (Borau et al., 2021). Interestingly, this idea does not apply on robots as well. Robots rather emphasize a masculine embodiment; even when they have female gender cues, they are somehow physically robust (Bernotat, Eyssel, & Sachse, 2019). Moreover, the literature highlights that robots are males according to the categorization process. Thus, to avoid a cognitive dissonance generated by female-gendered robots, the male ones are preferred in this context (Bernotat, Eyssel, & Sachse, 2019). The argument is sustained by other studies' results that outline a preference of individuals for male-gendered robots (Ladwig & Ferstl, 2018). However, these effects are situational and rather general. The labelling could be influenced by other variables, as the setting, or the situational context. Thus, while in general, a robot is generally preferred as male, when a robot works in a home environment a female is preferred (Ladwig & Ferstl, 2018).

The second research question (RQ2) draws on the way gender stereotypes are affecting the perceptions of virtual assistants and robots' competences. The present analysis confirms that stereotypes are occurring in interaction with various types of technology differently, according to the variables they are in relation with. In some instances, female-gendered technology is perceived as being more competent, while, in others, male-gendered technology performs better. It is remarqued that this could be especially due some natural gender attributes such as the female ability to be warm or empathic (Borau et al., 2021) or to male capacity to have physical power (Dufour & Ehrwein Nihan, 2016) in order to perform a certain task. While male agents are often perceived as being more competent in task solving, female agents are accepted more rapidly by individuals and the interaction is more qualitative due to humanlike perceived characteristics. In some specific instances, such as cooperative tasks (Pfeuffer & Hinz, 2019) or in persuasive contexts when the level of warmth and the lack of aggressiveness matters, female agents are perceived to perform better than male agents (Guo et al., 2020). Thus, the level of perceived competence depends on the way the task matches the gender of the agent. (Tay et al., 2013; Vega et al., 2019).

The third research question (RQ3) aims to analyze the main variables that are responsible for perceived gender stereotypes in technology. One of the most important variables is the setting, or the situational context. As most of the jobs are not considered gender neutral (Bryant, Borenstein, & Howard, 2020), analyzing the perspective from a single specific task (mechanics) is not sufficient as they are generating stereotypical responses that would be absent in gender neutral activities (banking) (Guo et al., 2020). Therefore, it would be relevant to analyze multiple tasks for obtaining accurate results. Another notable variable is the age of the user. Young and elderly individuals have different preferences for robot's gender when interacting with them (Watkins & Pak, 2020; Ladwig & Ferstl, 2018). Specifically, older individuals have stronger stereotyping believes towards female agents, compared to younger individuals (Pak, McLaughlin & Bass 2014; Ladwig & Ferstl, 2018). At the same time, a powerful effect is generated by the visual representation. While male design is rather neutral, female could be designed to look in a sexual manner and have feminized behaviors, such as smiling or winking (Gustavsson, 2005). Furthermore, the voice of an agent is a variable that has a strong influence on inducing different comfort levels for the individual. While it might be effective to design submissive voice agents to be associated with female traits and therefore

perceived as more human-like, this is another trigger for stereotyping technology. (Furqon et al., 2021).

The final research question (RQ4) emphasizes possible solutions for reducing gender stereotypes attached to technology. Current literature mentions the inability to implement gender-neutral technology at the moment (Ladwig & Ferstl, 2018). However, as stereotypes are often task related (Kuchenbrandt et al. 2014), some insights regarding potential solutions imply some elaboration of the technical prescript for the machine, in order to clarify, as much as possible, what the robot is able to do. This allows the individual to have a precise view of agent's attributes, before any stereotypes could arise regarding its performance. Likewise, positive consequences have been identified in forming believes on young children (Song-Nichols & Young, 2020; Okanda & Taniguchi, 2021). Through educational tools, children, in their path of becoming adults, can learn gender-neutral behaviors when interacting with both another person and with technology (Song-Nichols & Young, 2020). While the literature mentions the problematic aspects of gender stereotyping, it is a positive aspect that possible solutions are also offered for using technology as a tool to decrease gender stereotypes in real life situations. This could represent a very gratifying option and might provide a less discriminatory environment for future generations.

LIMITS, RESEARCH IMPLICATIONS, AND PERSPECTIVES

The limits of the study refer to three main aspects. First, the number of analyzed scientific papers included in the analysis is rather small. Although the relevant publications on the topic have been included, the emphasis mostly on virtual assistants and robots might lead to a limited perspective of the topic. Despite a thoughtful selection of the articles included in the systematic literature review, some research might not be identified. Likewise, by using exclusive English resources, important information written in different languages might have been missed. Future studies can increase the overview by incorporating gender-based studies on more technologies. Second, as the literature presents diverse results on the topic, due to situational factors and variables used, providing valid generalized perspectives is limited. Potential patterns for explaining and predicting gender-specific perceptions or behaviors within human-to-machine interaction can be developed by further studying the phenomenon in a more empirical manner. Finally, since the results are narratively synthesized, the interpretation of the literature might be subjective in patches. Thus, external experts should be involved for future systematic reviews to gain a more accurate perspective on the topic.

The implications of the present literature review are twofold. On one hand, the study manages to offer what is already known on the gender-based technology perspectives, emphasizing the main theories used in explaining stereotypical behavior and the variables that can induce stereotypes. Thus, it can provide a strong theoretical basis for future empirical approaches. The present paper identifies the implications of several variables that affect perceptions and competence of gendered technology, as typicality of the task, contextual situation, voice personality, agent personality traits (level of warmth vs dominance; agentic vs. communal traits), perceived trustworthiness, and cultural social roles. Thus, future research can explore these variables in-depth using an experimental approach. For instance, as most of the studies use a single stereotyping role to compare the effects on genders, the literature argues

for a more holistic approach by comparing multiple gender tasks in one study. Moreover, based on the solutions provided for reducing the gender stereotypes attached to technology, future studies might focus on analyzing the implementation process of these recommendations and confirm their validity.

On the other hand, the gained information can be used in different domains, at the business and industry levels. For instance, while in the organizational communication domain virtual agents are working alongside with human employees, gender stereotypes can be corrected by acknowledging their existence and implications. As technology is more present in pedagogy, the educational field can benefit from teaching children a politically correct approach to treat virtual assistance and robots and, consequently apply the neutral-gender labeling in human-to-human interaction. Having increased assistive technology and virtual caregivers, the medical field can better understand human-to-machine communication of both young and elderly users. Nevertheless, the information gained at the research level can be useful for technology and applications' designers. Considering that gender stereotypes used in human-to-machine interaction can degenerate and further used within the human-to-human communication, a machine gender-neutral perspective can have a vital educational role.

REFERENCES

Adams, N. R. (2019). How artificial intelligence works. *Becoming AI*, 2-4.

Ahn, J., Kim, J., & Sung, Y. (2022). The effect of gender stereotypes on artificial intelligence recommendations. *Journal of Business Research*, *141*, 50-59.

Bereczki, E., & Kárpáti, A. (2018). Teachers' beliefs about creativity and its nurture: A systematic review of the recent research literature. *Educational Research Review*, *23*, 25-56. http://doi.org/10.1016/j.edurev.2017.10.003

Bernotat, J., Eyssel, F., & Sachse, J. (2019). The (Fe)male Robot: How Robot Body Shape Impacts First Impressions and Trust Towards Robots. *International Journal of Social Robotics*, *13*(3), 477-489. http://doi.org/10.1007/s12369-019-00562-7

Bisconti, P., & Perugia, G. (Accepted/In press). How Do We Gender Robots? Inquiring the Relationship Between Perceptual Cues and Context of Use. In *GenR 2021 Workshop on Gendering Robots: Ongoing (Re)configurations of Gender in Robotics.*

Brahnam, S., & De Angeli, A., (2012). Gender affordances of conversational agents. *Interacting with Computers*, *24*(3), 139-153.

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. http://doi.org/10.1002/mar.21480

Carpenter, J., Davis, J., Erwin-Stewart, N., Lee, T., Bransford, J., & Vye, N., (2009). Gender Representation and Humanoid Robots Designed for Domestic Use. *International Journal of Social Robotics*, *1*(3), 261-265.

Bryant, D., Borenstein, J. and Howard, A., 2020. Why Should We Gender?. *Proceedings of the 2020 ACM/IEEE International Conference on Human-Robot Interaction*, 13-20.

Cercas Curry, A., Robertson, J., & Rieser, V. (2020). Conversational Assistants and Gender Stereotypes: Public Perceptions and Desiderata for Voice Personas. In *Proceedings of the Second Workshop on Gender Bias in Natural Language Processing*, pp. 72–78, Barcelona, Spain (Online). Association for Computational Linguistics.

Chang, R., Lu, H., & Yang, P. (2018). Stereotypes or golden rules? Exploring likable voice traits of social robots as active aging companions for tech-savvy baby boomers in Taiwan. *Computers in Human Behavior*, *84*, 194-210.

Chita-Tegmark, M., Lohani, M., & Scheutz, M. (2019). Gender Effects in Perceptions of Robots and Humans with Varying Emotional Intelligence. 2019 14Th ACM/IEEE *International Conference on Human-Robot Interaction (HRI)*. http://doi.org/10.1109/hri.2019.8673222

Costa, P. (2018). Conversing with Personal Digital Assistants: on Gender and Artificial Intelligence. *Journal of Science and Technology of the Arts*, *10*(3), 59-72. https://doi.org/10.7559/citarj.v10i3.563Dornis, T. (2020). Artificial Creativity: Emergent Works and the Void in Current Copyright Doctrine. *Yale Journal of Law & Technology*, *XXII*(1). http://dx.doi.org/10.2139/ssrn.3451480

Dufour, F., & Ehrwein Nihan, C. (2016). Do Robots Need to Be Stereotyped? Technical Characteristics as a Moderator of Gender Stereotyping. *Social Sciences*, *5*(3), 27.

Ellemers, N. (2018). Gender stereotypes. *Annual Review of Psychology*, *69*, 275-298. https://doi.org/10.1146/annurev-psych-122216-011719

Eyssel, F., Hegel, F. (2012). (S)he's Got the Look: Gender Stereotyping of Robots 1. *Journal of Applied Social Psychology*, *42*(9), 2213-2230

Ernst, C., & Herm-Stapelberg, N. (2020). Gender Stereotyping's Influence on the Perceived Competence of Siri and Co. *Proceedings of The Annual Hawaii International Conference on System Sciences*. http://doi.org/10.24251/hicss.2020.544

Ferrando, F. (2014). Is the post-human a post-woman? Cyborgs, robots, artificial intelligence and the futures of gender: a case study. *European Journal of Futures Research*, *2*(1).

Furqon, S., Busro, B., Hambali, R., Albustomi, A., & Hannah, N. (2021). Gender in Artificial Intelligence (AI-Android) on Sophia and (AI-Virtual) on Lilmiquela. *IOP Conference Series: Materials Science and Engineering*, *1098*(3), 032091. http://doi.org/10.1088/1757-899x/1098/3/032091

Ghazali, A., Ham, J., Barakova, E., & Markopoulos, P. (2018). Effects of Robot Facial Characteristics and Gender in Persuasive Human-Robot Interaction. *Frontiers in Robotics And AI*, *5*. http://doi.org/10.3389/frobt.2018.00073

Guo, Y., Liu, D., Yin, X., & Xu, S. X. (2021). "She is not just a computer": Gender role of AI chatbots in debt collection. In *International Conference on Information Systems, ICIS 2020 - Making Digital Inclusive: Blending the Local and the Global* (International Conference on Information Systems, ICIS 2020 - Making Digital Inclusive: Blending the Local and the Global). Association for Information Systems.

Gustavsson, E. (2005). Virtual Servants: Stereotyping Female Front-Office Employees on the Internet. *Gender, Work and Organization*, *12*(5), 400-419. http://doi.org/10.1111/j.1468-0432.2005.00281.x

Guzman, A., & Lewis, S. (2019). Artificial intelligence and communication: A Human–Machine Communication research agenda. *New Media &Amp; Society*, *22*(1), 70-86. http://doi.org/10.1177/1461444819858691

Haake, M., & Gulz, A. (2008). Visual Stereotypes and Virtual Pedagogical Agents. *Educational Technology & Society*, *11*, 1-15.

Hentschel, T., Braun, S., Peus, C., & Frey, D. (2018). The communality-bonus effect for male transformational leaders – leadership style, gender, and promotability. *European Journal of Work and Organizational Psychology, 27*, 112–125. http://doi.org/10.1080/1359432X.2017.1402759

Hentschel, T., Heilman, M.E., & Peus, C.V. (2019). The Multiple Dimensions of Gender Stereotypes: A Current Look at Men's and Women's Characterizations of Others and Themselves. *Frontiers in Psychology, 30*. https://doi.org/10.3389/fpsyg.2019.00011

Kim, A., Cho, M., Ahn, J., & Sung, Y., 2019. Effects of Gender and Relationship Type on the Response to Artificial Intelligence. *Cyberpsychology, Behavior, and Social Networking*, *22*(4), 249-253.

Kuchenbrandt, D., Häring, M., Eichberg, J., Eyssel, F., & André, E. (2014). Keep an Eye on the Task! How Gender Typicality of Tasks Influence Human–Robot Interactions. *International Journal of Social Robotics*, *6*(3), 417-427.

Ladwig, R., & Ferstl, E. (2018). What's in a name?. *Proceedings of The 4Th Conference On Gender & IT - Genderit '18*. http://doi.org/10.1145/3196839.3196851

Lauzadyte-Tutliene, A., & Mikuciauskaite, P. (2022). Analysis of gender wage gap in Lithuania. *Economics and Sociology, 15*(2), 172-185. doi:10.14254/2071- 789X.2022/15-2/11

Law, T., Chita-Tegmark, M., & Scheutz, M., 2020. The Interplay Between Emotional Intelligence, Trust, and Gender in Human–Robot Interaction. *International Journal of Social Robotics*, *13*(2), 297-309.

Lee, E. (2003). Effects of "gender" of the computer on informational social influence: the moderating role of task type. *International Journal of Human-Computer Studies*, *58*(4), 347-362. http://doi.org/10.1016/s1071-5819(03)00009-0

McDonnell, M., & Baxter, D. (2019). Chatbots and Gender Stereotyping. *Interacting with Computers*, *31*(2), 116-121. http://doi.org/10.1093/iwc/iwz007Mezei, P. (2020). From Leonardo to the Next Rembrandt – The Need for AI-Pessimism in the Age of Algorithms. *UFITA*, *2*, 390-429. https://doi.org/10.5771/2568-9185-2020-2-390.

Nass, C., & Moon, Y., (2000). Machines and Mindlessness: Social Responses to Computers. *Journal of Social Issues*, *56*(1), 81-103.

Nass, C., Moon, Y., & Green, N. (1997). Are Machines Gender Neutral? Gender-Stereotypic Responses to Computers with Voices. *Journal of Applied Social Psychology*, *27*(10), 864-876.

Nag, P., & Yalçın, Ö. (2020). Gender Stereotypes in Virtual Agents. *Proceedings of the 20th ACM International Conference on Intelligent Virtual Agents*.

Neuteboom, S., & de Graaf, M. (2021). Cobbler Stick with Your Reads: People's Perceptions of Gendered Robots Performing Gender Stereotypical Tasks. *TRAITS Workshop Proceedings (arXiv:2103.12679) held in conjunction with Companion of the 2021 ACM/IEEE International Conference on Human-Robot Interaction, March 2021*.

Nomura, T., & Kinoshita, Y. (2015). Gender Stereotypes in Cultures: Experimental Investigation of a Possibility of Reproduction by Robots in Japan. *2015 International Conference on Culture and Computing (Culture Computing)*. http://doi.org/10.1109/culture.and.computing.2015.9

Okanda, M., & Taniguchi, K. (2021). Is a robot a boy? Japanese children's and adults' gender-attribute bias toward robots and its implications for education on gender stereotypes. *Cognitive Development*, *58*, 101044.

Otterbacher, J., & Talias, M. (2017). She's too Warm/Agentic!. *Proceedings of The 2017 ACM/IEEE International Conference On Human-Robot Interaction*. http://doi.org/10.1145/2909824.3020220

Powers, A., Kramer, A., Lim, S., Kuo, J., Sau-lai, L., & Kiesler, S. (2005). Eliciting information from people with a gendered humanoid robot. ROMAN 2005. *IEEE International Workshop on Robot and Human Interactive Communication*. http://doi.org/10.1109/roman.2005.1513773

Pak, R., McLaughlin, A., & Bass, B. (2014). A multi-level analysis of the effects of age and gender stereotypes on trust in anthropomorphic technology by younger and older adults. *Ergonomics*, *57*(9), 1277-1289.

Pfeuffer, N., Adam, M., Toutaoui, J., Hinz, O., & Benlian, A. (2019). Mr. and Mrs. Conversational Agent - Gender Stereotyping in Judge-Advisor Systems and the Role of Egocentric Bias. *ICIS 2019 Proceedings*. 2. https://aisel.aisnet.org/icis2019/human_computer_interact/human_computer_interact/2

Pfeifer, A., & Lugrin, B. (2018). Female Robots as Role-Models? - The Influence of Robot Gender and Learning Materials on Learning Success. *Lecture Notes in Computer Science*, 276-280. http://doi.org/10.1007/978-3-319-93846-2_51

Reich-Stiebert, N., & Eyssel, F., 2017. (Ir)relevance of Gender?. *Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction*.

Samoliuk, N., Bilan, Y., Mishchuk, H., & Mishchuk, V. (2022). Employer brand: key values influencing the intention to join a company. *Management & Marketing. Challenges for the Knowledge Society, 17*(1), 61-72. https://doi.org/10.2478/mmcks-2022-0004

Shava, H. (2021). The relationship between service quality and customer satisfaction in the South African mobile network telecommunications industry. *Journal of International Studies, 14*(2), 70-83. doi:10.14254/2071-8330.2021/14-2/5

Song-Nichols, K., & Young, A. (2020). Gendered Robots Can Change Children's Gender Stereotyping. *Conference: CogSci 2020At: Toronto*

Tay, B., Jung, Y., & Park, T. (2014). When stereotypes meet robots: The double-edge sword of robot gender and personality in human–robot interaction. *Computers in Human Behavior, 38*, 75-84.

Thellman, S., Hagman, W., Jonsson, E., Nilsson, L., Samuelsson, E., & Simonsson, C. et al. (2018). He is not more persuasive than her. *Proceedings of the 18Th International Conference On Intelligent Virtual Agents*. http://doi.org/10.1145/3267851.3267862

Townsend, D., & Hunt, R. (2019). Entrepreneurial action, creativity, & judgment in the age of artificial intelligence. *Journal of Business Venturing Insights, 11*, e00126. https://doi.org/10.1016/j.jbvi.2019.e00126

Vega, A., Ramírez-Benavides, K., Guerrero, L., & López, G. (2019). Evaluating the Nao Robot in the Role of Personal Assistant: The Effect of Gender in Robot Performance Evaluation. *13th International Conference on Ubiquitous Computing and Ambient Intelligence UCAmI 2019*.

Veletsianos, G., Scharber, C., & Doering, A. (2008). When sex, drugs, and violence enter the classroom: Conversations between adolescents and a female pedagogical agent. *Interacting with Computers*, *20*(3), 292-301. http://doi.org/10.1016/j.intcom.2008.02.007

Watkins, H., & Pak, R. (2020). Investigating User Perceptions and Stereotypic Responses to Gender and Age of Voice Assistants. *Proceedings of The Human Factors and Ergonomics Society Annual Meeting*, *64*(1), 1800-1804. http://doi.org/10.1177/1071181320641434

Wang, Y., & Young, J., E. (2014) Beyond "Pink" and "Blue": Gendered Attitudes Towards Robots in Society. *Proceedings of Gender and IT Appropriation (GenderIT'14)*, 49 -59

Weßel, M., Ellerich-Groppe, N., & Schweda, M. (2021). Gender Stereotyping of Robotic Systems in Eldercare: An Exploratory Analysis of Ethical Problems and Possible Solutions. *International Journal of Social Robotics*. https://doi.org/10.1007/s12369-021-00854-x

Woinaroschy, A. (2020). Personal considerations about creativity and artificial intelligence. *Journal of Engineering Sciences and Innovation, 5*(1), 63-68.

Authors' Note

All correspondence should be addressed to:
Miruna-Valeria CRĂIUȚ
Department of Communication, Public Relations, and Advertising
Faculty of Political, Administrative, and Communication Sciences
Babeș-Bolyai University, Cluj-Napoca, Romania
E-mail: craiutmiruna@gmail.com

Ioana IANCU
Department of Communication, Public Relations, and Advertising
Faculty of Political, Administrative, and Communication Sciences
Babeș-Bolyai University, Cluj-Napoca, Romania
E-mail: iancu@fspac.ro

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

Human Technology

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

office@csr-pub.eu

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