Infocommunications Journal

A PUBLICATION OF THE SCIENTIFIC ASSOCIATION FOR INFOCOMMUNICATIONS (HTE)

ISSN 2061-2079

Special Issue

Special Issue on Cognitive Infocommunications

GUEST EDITORS, AUTHORS

Guest Editors, Authors and Co-Authors of the Special Issue on Cognitive Infocommunications 1

PAPERS FROM OPEN CALL

Computer-assisted training programs to enhance adaptive competencies in adolescents with intellectual disabilities. A systematic review ..... *Selene Mezzalira, Cristiano Scandurra, Nelson Mauro Maldonato, and Vincenzo Bochicchio* 2

The responses to sad and happy infant faces are negatively associated with Maternal Emotional Availability ..... *Carla Nasti, Sonia La Resta, Stefania Paternoster Silvia Perzolli, Simona De Falco, and Vincenzo Paolo Senese* 9

Does parenting affect recognition of emotions conveyed by children? ..... *Terry Amorese, Marialucia Cuciniello, Claudia Greco, Gennaro Cordasco, and Anna Esposito* 16

The Effects of Immersion Level, Human Characteristics, and a Virtual Scale on Exocentric Distance Perception..... *Tibor Guzsvinecz, Judit Szűcs, and Erika Perge* 24

Learning 3D Computer-Aided Design on Immersive Platforms of Augmented and Virtual Reality ..... *Chenxin Wu, Mengjie Huang, Rui Yang, Zhaoyu Xu, Wenxin Sun, and Liu Wangi* 32

Towards Automated Musical Anamnesis for Music-based Intervention in Dementia Patients ..... *Fabian Simmank, Katarzyna Grebosz-Haring, Thomas Ballhausen, Christian Thomay, Martin Biallas, and Markus Tauber* 40

Navigating in the Law of Digital Reality: Contractual and Jurisdictional Challenges in a Borderless World ..... *Barna Arnold Keserű* 49

Introducing the New Concept of Personalized Digital Tourism (PDT) ..... *Judit Grotte* 58

The Use of Design Thinking Methodology in the Design and Development of an Interactive Web-based Personalized Trip Planning Tool: A Case Study of Thailand..... *Tiparpa Soongswang, Kawin Srisilpavongse, Kritawat Kraiwitchaocharoen, Kiartnarin Udomlapsakul, Nuttayos Charukulvanich, Kritchavit Thippayajindakul, Nattakit Pisitsup, Burapa Chinwatanakit, Maia Kawamura, Mathis Person, Napatra Navanugraha, Tai Tienboon, Natdanai Aramrueng, Chawin Sungkhapong, Gevalin Wongweerakit, and Aung Pyae* 68

CALL FOR PAPER / PARTICIPATION

IEEE/IFIP NOMS2026 / IEEE/IFIP Network Operations and Management Symposium 2026 Róma, Italy 89

ADDITIONAL

Guidelines for our Authors 88

Technically Co-Sponsored by

IEEE ComSoc™ IEEE Communications Society

hte

IEEE HUNGARY SECTION

Indexing information

Infocommunications Journal is covered by Inspec, Compendex and Scopus.
Infocommunications Journal is also included in the Thomson Reuters – Web of ScienceTM Core Collection, Emerging Sources Citation Index (ESCI)

Infocommunications Journal

Technically co-sponsored by IEEE Communications Society and IEEE Hungary Section

Supporters

FERENC VÁGUJHELYI – president, Scientific Association for Infocommunications (HTE)

The publication was produced with the support of the Hungarian Academy of Sciences and the NMHH

Editorial Office (Subscription and Advertisements)**:**
Scientific Association for Infocommunications
H-1051 Budapest, Bajcsy-Zsilinszky str. 12, Room: 502
Phone: +36 1 353 1027 • E-mail: info@hte.hu • Web: www.hte.hu

Articles can be sent also to the following address:
Budapest University of Technology and Economics
Department of Telecommunications and Media Informatics
Phone: +36 1 463 4189 • E-mail: pvarga@tmit.bme.hu

Subscription rates for foreign subscribers: 4 issues 13.700 HUF + postage

Publisher: PÉTER NAGY

HU ISSN 2061-2079 • Layout: PLAZMA DS • Printed by: FOM Media

Guest Editors, Authors and Co-authors

Special Issue

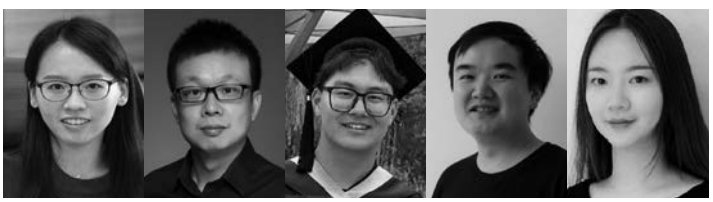
Special Issue on Cognitive Infocommunications

Guest Editors

Péter Baranyi, Anna Esposito,
Carl Vogel*

Authors

Selene Mezzalira, Cristiano Scandurra,
Nelson Mauro Maldonato,
Vincenzo Bochicchio; Carla Nasti,
Sonia La Resta, Stefania Paternoster,
Silvia Perzolli, Simona De Falco,
Vincenzo Paolo Senese;
Terry Amorese, Marialucia Cuciniello*,
Claudia Greco*, Gennaro Cordasco*;
Tibor Guzsvinecz, Judit Szűcs,
Erika Perge; Chenxin Wu,
Mengjie Huang, Rui Yang,
Zhaoyu Xu, Wenxin Sun, Liu Wangi;
Fabian Simmank,
Katarzyna Grebosz-Haring,
Thomas Ballhausen, Christian Thomay,
Markus Tauber, Martin Biallas*;
Barna Arnold Keserű; Judit Grotte;
Tiparpa Soongswang,
Kritawat Kraiwitchaocharoen,
Napatra Navanugraha,
Chawin Sungkhapong, Aung Pyae,
Kawin Srisilpavongse*,
Kiartnarin Udomlapsakul*,
Nuttayos Charukulvanich*,
Kritchavit Thippayajindakul*,
Nattakit Pisitsup*, Burapa Chinwatanakit*,
Maia Kawamura*, Mathis Person*,
Tai Tienboon*, Natdanai Aramrueng*,
Gevalin Wongweerakit*



* without photo

Computer-assisted training programs to enhance adaptive competencies in adolescents with intellectual disabilities. A systematic review

Selene Mezzalira [1 *], Cristiano Scandurra [2], Nelson Mauro Maldonato [3], and Vincenzo Bochicchio [4]

***Abstract*—Intellectual disability (ID) involves deficits in intellectual and adaptive functioning specifically related to conceptual, social, and practical life domains. Computer-assisted training programs have been shown to enhance adaptive competencies of adolescents with ID, thus helping them to better manage their everyday life and to foster their social inclusion and integration. The present work is aimed at reviewing the existing literature on computer-assisted interventions devoted to adolescents with ID highlighting their actual efficacy and strengths. Implications for future research and practice are discussed.**

***Index Terms*—Intellectual Disabilities; Adolescents; Computer-Assisted; Training; Adaptive Competencies.**

I. Introduction

The 5th edition of the *Diagnostic and Statistical Manual of Mental Disorders* [1] defines Intellectual Disability (ID), also known as Intellectual Developmental Disorder (IDD), as a condition with onset during the developmental period, characterized by deficits in intellectual and adaptive functioning specifically related to conceptual, social, and practical life-domains. Intellectual disability is related to sensory impairments [2]. It is worth noting that the outer world is perceived by human beings through sight more than other sensory modalities such as olfaction [3].

Albeit almost totally unexplored until the last century, the use of computer-assisted tools to enhance the education and training of individuals with ID has witnessed an important increase in recent years [4], and has also been suggested to be very important for psychology [5]. For instance, employing the so-called "serious games" – digital games whose main aim is not much to entertain people, but rather to teach them new skills and enhance their already possessed skills – has been proven effective in training individuals with ID [6,7]. Actually, few reviews have been conducted on the use and efficacy of assistive technology as a self-management tool for people with ID [8], and, more generally, on the efficacy of computer-based tools to enhance different skills of individuals with ID in daily living [9], academic knowledge [8], and other important areas of functioning such as communication, employment, and leisure [11]. This paper contributes to the scientific field of Cognitive InfoCommunications [12,13], which refers to the link between the research fields of infocommunications and cognitive sciences as well as their relationship, whose goal is "to provide a systematic view of how cognitive processes can co-evolve with infocommunications devices" [12]. An infocommunication system generally refers to "any kind of hardware or software component that collects and stores information and allows users to interact with this information" [12]. Therefore, the present study adds to the literature addressing infocommunication systems by investigating how these devices can aid young individuals with ID to acquire new competencies or strengthen those already acquired.

The current systematic review is focused not on mere knowledge acquisition, but rather on behavioral competency enhancement. As opposed to "knowledge," which can be regarded as the result of information acquisition through learning, "competency" refers to the ability of applying and utilizing acquired knowledge to carry out tasks and solve problems in professional, social, and vocational life domains.

II. Method

We reviewed the existing literature on computer-assisted interventions devoted to youth with ID, carrying out a systematic search and selecting relevant references in the following databases: PubMed, Scopus, Web of Science, and PsycInfo. Search terms were chosen with the aim of satisfying all dimensions of interest. The keywords we used for our search were the following: (intellectual disabilit*) AND (adolescent*) AND (compentenc*) AND (training OR intervention). On April 6, 2023, a literature search was carried out in order to create a database of scientific articles relevant to the impact of computer-assisted programs used to enhance various competencies in adolescents with ID. Inclusion criteria consisted of selecting experimental studies only, studies involving samples of adolescent population (aged 12 to 18 years) with a diagnosis of ID and without secondary psychic or physical diagnoses. We set a specific temporal boundary to cover the period from 2000 to present. Exclusion criteria involved studies published before 2000, records written in other languages than English, theoretical studies, and studies concerning ID individuals with other concurrent diagnoses (e.g., Autism Spectrum Disorder and Attention-Deficit/Hyperactivity Disorder).

A total of 562 results were found through database search. After removal of duplicates, eligibility criteria were applied. A total of 484 records were screened based on inclusion criteria.

[1] School of Engineering, University of Basilicata, Potenza, Italy; (e-mail: selene.mezzalira@unibas.it) (* corresponding author)

[2] Department of Neurosciences, Reproductive Sciences, and Dentistry, University of Naples Federico II, Napoli, Italy; (e-mail: cristiano.scandurra@unina.it)

[3] Department of Neurosciences, Reproductive Sciences, and Dentistry, University of Naples Federico II, Napoli, Italy; (e-mail: nelsonmauro.maldonato@unina.it)

[4] Department of Humanities, University of Calabria, Rende, Italy; (e-mail: vincenzo.bochicchio@unical.it)

DOI: 10.36244/ICJ.2025.6.1

417 records were excluded in the screening process, which resulted in the retrieval of 67 records. Among the 67 full-texts assessed for eligibility, 52 records did not meet the inclusion criteria, and were thus excluded from the systematic search. Specifically, 28 did not focus on the research question, 3 were not in English, 17 involved samples not including adolescents, and 4 were theoretical (i.e., not experimental). The systematic search finally led to the inclusion of 15 articles. The details of this procedure are illustrated in Figure 1.

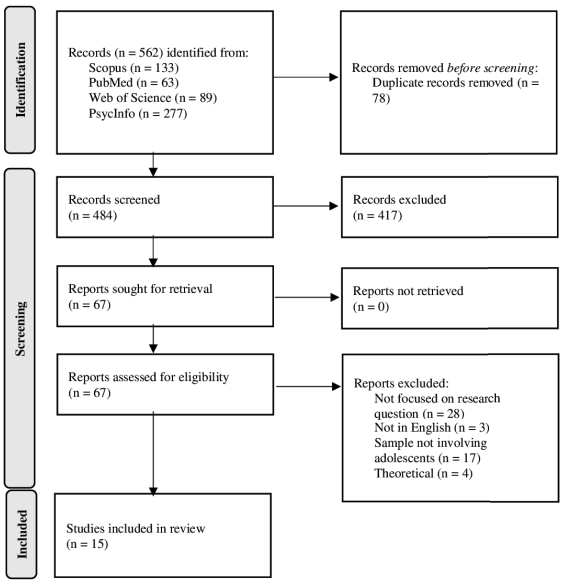


Figure 1. PRISMA 2020 flow diagram

III. Results

The focus, sample, type of study, and results of the 15 included studies are synthesized in Table 1.

TABLE II
Full Text Sources Retained

Author(s), Year	Sample	Type of study	Results
Bouck et al., 2009	3 individuals with mild ID, 12 y.o.	Multiple probe research design	A pentop computer can be effectively used in teaching multiplication skills to students with mild ID
Cannella-Malone et al., 2012	3 individuals with moderate to severe ID, 15 y.o.	Adapted alternating treatments design within a multiple probe across participants design	Video prompting is effective to teach new skills to individuals with moderate to severe ID
Cihak, Kessler, & Alberto, 2008	4 students with moderate to severe ID, 16-17 y.o.	Multiple probe design across participants	Students with moderate to severe ID can learn to effectively use handheld prompting systems to increase autonomy and independence
Creech-Galloway et al., 2013	4 students with moderate ID, 15-17 y.o.	Multiple probe design across participants	Students with moderate ID are able to learn to use the Pythagorean theorem to solve problems
Gardner & Wolfe, 2015	4 adolescents with mild to moderate developmental disabilities, 13-14 y.o.	Multiple baseline design across participants	Video prompting is effective in teaching individuals with developmental disabilities the skill of washing dishes
Goo, Therrien, & Hua, 2016	4 students with mild to moderate ID, 17-18 y.o.	Multiple probe design across participants	Computer-based video instructional programs alone are effective in facilitating the acquisition and generalization of grocery purchasing skills by individuals with ID
Hammond et al., 2010	3 students with moderate ID, 12-14 y.o.	Combined multiple probes across participants and replicated across tasks	Video modeling is effective in teaching students with ID to independently use iPods
Hansen & Morgan, 2008	3 individuals with ID, 16-17 y.o.	Multiple baseline design across participants	Computer-based instructions are effective in teaching grocery store purchasing skills to individuals with ID
Hudson, 2019	3 subjects with moderate to severe ID, 13-16 y.o.	Single case multiple probe design across participants	iPad-delivered early literacy intervention and self-monitoring can be effective on the acquisition of early literacy skills in some individuals with ID
Kim, Blair, & Lim, 2014	3 subjects with severe ID, 17 y.o.	Multiple probe design across participants	The use of tablet assisted Social Stories™ can decrease disruptive behavior and increase academic engagement in individuals with severe ID

Mechling, Gast, & Barthold, 2003	3 students with moderate ID, 16-18 y.o.	Multiple probe design across participants	Multimedia programs alone are effective in teaching acquisition and generalization of the use of a debit card to make purchases on an automated payment machine
Palmqvist et al., 2020	38 individuals (IG: N=17; CG N=21). IG: 17.91 y.o. (mean) CG: 7.65 y.o. (mean)	Mixed study (quantitative and qualitative)	A tablet-based program offers a potentially feasible intervention for teaching everyday planning skills to adolescents with ID, who need however more time to get familiarized with the program when compared to typically developing population
Sheriff & Boon, 2014	3 students with mild ID, 13-14 y.o.	Multiple probe single-subject research design	The ability of students with ID to solve word problems using computer-based graphic organizers increase when compared to traditional instructional tools
Taber-Doughty et al., 2011	3 students with mild ID, 12-13 y.o.	Alternating treatment design with a follow-up and withdrawal probe	Video prompting and video modeling are effective in teaching cooking skills to students with mild ID
Van der Molen et al., 2010	95 subjects with mild to moderate ID (IG_1: adaptive training, N=41; IG_2: non-adaptive training, N=27; CG: N=27), 13-16 y.o.	Randomized, single-blind controlled trial	Working memory can be successfully trained in adolescents with mild to borderline ID

ID=intellectual disabilities; IG=intervention group; CG=control group; y.o.=years old

The findings of the included articles point to the efficacy of video-based assistive tools in training various skills to youth with ID. For instance, Gardner & Wolfe [14] analyzed the effectiveness of a video modeling procedure on the ability that adolescents with mild to moderate ID had in acquiring daily living skills. The results showed that using a video prompting with an error correction procedure was effective in teaching these individuals to learn to wash dishes. Among other important daily living skills, the capacity to make purchases in different settings is extremely important for independent functioning of individuals with ID. Since purchasing generally involves complex chains of steps that change according to the setting, Mechling et al. [15] analyzed the effectiveness of a multimedia method comprised of interactive computer program, video captions, and still photographs to teach students with moderate ID to use a debit card and an automated payment machine to make purchases, showing its effectiveness in teaching adolescent individuals with moderate ID to use a debit card to make purchases through an automated payment machine. A multimedia computer-based instructional tool has been utilized also by Hansen and Morgan [16], who evaluated its efficacy in teaching grocery store purchasing skills to high-school students with ID, who were able to enhance their purchasing skills, and to generalize them in different grocery stores in a 30-day follow-up. Similar results have been attained by Goo et al. [17], who evaluated the efficacy of a computer-based video instructional program aimed at teaching grocery purchasing skills to high-school students with moderate ID. The results confirmed that computer-based video instruction alone was effective in allowing adolescent students with ID to acquire and generalize grocery purchasing skills. Overall, these findings point to the importance of using technological devices to help individuals with ID acquire or strengthen commercial competencies, with particular focus on making purchases.

Video modeling has been utilized by Hammond et al. [18] to examine its efficacy on accurate and independent use of an iPod by adolescents with moderate ID. The study aimed at teaching students to watch a movie, listen to music, and look at photos on an iPod. Through video modeling, participants acquired the ability to independently use the iPod, also maintaining most of the acquired skills on follow-up probe trials, confirming the effectiveness of this tool in teaching adolescents with ID to use portable technological devices. Taber-Doughty et al. [19] demonstrated that using video prompting and video modeling is effective in teaching individuals with mild ID to independently complete novel recipes and improve their accuracy over baseline levels. Cannella-Malone et al. [20] used an iPod Touch to compare the effects of video prompting on the ability of students with moderate to severe ID to acquire daily living skills. Overall, these results also indicated that video prompting is an effective technology for teaching new skills to adolescents with ID.

Palmqvist et al. [21] investigated the feasibility of an everyday planning tablet-based training program for individuals with ID comparing a group of high-school students with mild to moderate ID and a group of typically developing children attending primary school. After matching the two groups on mental age, the study revealed that the group of ID individuals needed to familiarize with the program before being as active as the participants in the control group when using the tablet-based tool. Even though, in the beginning, the

subjects with ID seemed to use different strategies compared to those of the control group, nonetheless the training program helped a subgroup of them to develop effective strategies and to use them effectively. Ultimately, these results indicated that individuals with ID generally needed more time to learn to use the program, but were still able to learn as much as the subjects of the control group. This also points to the importance to consider the temporal duration of the use of computerized tools when assessing digital support for subjects with ID.

Van der Molen et al. [22] demonstrated that working memory (WM) related skills can be successfully taught to adolescents with mild to borderline ID who attended special education classes through a computer-based training. The researchers witnessed a significant improvement in verbal short-term memory (STM) from pre- to post-testing in the group that received the training, as compared with the control group. The beneficial effects of the program on verbal STM were maintained at follow-up. These results clearly indicated that WM-related competencies can be effectively trained in individuals with ID, indicating that technological devices can aid individuals with ID in strengthening specific cognitive functions such as WM.

Mathematics is widely considered a relevant and critical content domain for education and evaluation of all students, but its mastery can be hard to attain for individuals with ID. Sheriff and Boon [23] examined the effects of computer-assisted graphic organizers, based on a specific digital software, to solve mathematical one-step word problems in targeted individuals with ID. The authors aimed at evaluating the effectiveness of computer-based graphic organizers to help these individuals to solve simple mathematical problems. During the baseline phase, students completed a worksheet consisting of few functional word problems using traditional tools. Subsequently, in the intervention and maintenance phases, students had to complete the word problems using a computer-based graphic organizer. The results indicated that all participants enhanced their ability to solve the word problems using computer-based graphic organizers, as compared to more typical instructional tools. Furthermore, all participants' performance levels, which were acquired in the intervention phase, were retained during the maintenance phase, confirming the effectiveness of using computer-based graphic organizers to enhance the academic performance of students with ID. Bouck et al. [24] examined the effectiveness of a pentop computer in teaching multiplication facts to middle school students with mild ID. The authors assessed the students' learning of different multiplication facts over an intervention period of 2-3 weeks, after which the authors assessed the students' ability to solve multiplication problems without this tool. The authors witnessed an improvement of the percentage of correct math facts completed by all participants, supporting the hypothesis of the efficacy of the use of pentop computers in teaching multiplication skills to students with mild ID. In a similar vein, Creech-Galloway et al. [25] analyzed the effects that a simultaneous prompting procedure had in teaching adolescents with moderate ID to use the Pythagorean theorem to solve real-life scenarios that were shown on a short video using an i-Pad. The results showed that all participants learned to use and generalize the Pythagorean theorem formula, confirming that students with moderate ID are able to learn how to use the Pythagorean theorem in real-life situations and to apply it to new situations.

Within the field of cognitive infocommunications, the concept of "mathability" refers to a dimension whose purpose is to investigate combinations of artificial and natural cognitive capabilities relevant to mathematics [26]. This notion has been used to refer to devices with high mathematical and logical potential, which can be used in aiding both further development of sciences and everyday education [27]. Notably, the greater is the mathability of the technological device or application, the poorer student's mathematical skills could be [28]. ID persons tend to have lower math-related skills if compared to typically developing individuals. Therefore, these persons might essentially benefit from the aid of the device-based mathability to the aim of solving a vast array of mathematical, calculus-based, and logical problems. Today, however, since uncontrolled computer-based self-education can be risky, especially in adolescents, it is necessary to focus more on abilities of selection and assessment of gathered information alongside reflection on the obtained result [29].

Individuals with ID typically score lower on standardized reading measures when compared to subjects without ID. It has been argued that this might be due to the fact that measures are based on traditional print materials and do not give these individuals the opportunity to access supported electronic texts (eTexts) [30]. Since eTexts are available in different formats, non-readers and especially individuals with ID have nowadays more opportunities to familiarize with the written word. Based on this premise, Douglas et al. [30] evaluated the effects of different types of supports on the reading and listening comprehension of students with moderate ID, finding that two of the specific eText supports considered (i.e., reading the text out loud and graphic organizers) were effective in supporting their text comprehension. Similarly focusing on literacy skills, Hudson [31] evaluated the efficacy of an iPad-delivered early literacy intervention and self-monitoring on the acquisition of early literacy skills in individuals with moderate to severe ID. The results of the study were mixed, thus pointing to the need to deepen this type of research, given that only two of three participants had increasingly higher percentage of independent correct responses after completion of the early literacy skills lessons in their level. Cihak et al. [32] examined the efficacy of using a handheld prompting system in helping students with moderate to severe ID to independently transition between an ordered set of tasks, demonstrating that these individuals could learn to effectively use handheld prompting systems to increase autonomy and independence. Finally, Kim et al. [33] examined the use of tablet assisted Social Stories™ intervention for high-school students with severe ID with behavioral problems that hindered their learning process. The

results indicated that this type of intervention decreased maladaptive behaviors and increased academic engagement of these individuals, who also demonstrated to be able to generalize these behaviors and maintain them over time. Overall, autonomy, independence, and self-engagement have been thus shown to have the potential to be strengthened through the use of technological devices in individuals with ID.

IV. Discussion

Even though concerns have been raised as to the relationship between the use of digital devices and the individual's development [34], showing for instance how digital media inhibit self-regulatory private speech in children [35], overall contemporary technology has been found to significantly improve the quality of life of individuals with ID, and provide them with skills that they can utilize for social inclusion. The use of modern technologies as instructional tools has become more and more prevalent in both general and special education. Furthermore, the significance of assisted technologies has been stressed by a World Health Organization statement focusing on the use of infocommunication technologies to facilitate the access to services for individuals with special needs and to remove the obstacles they encounter in their social integration [36]. However, existing technological devices only partially meet the needs of these individuals [37]. In fact, much needs to be done in order for ID individuals to be provided with appropriate technology in the special centers they attend [38]. To date, little literature exists as to the benefits of the use of technological tools to improve ID individuals' skills and abilities [39]. This paper aimed at filling this gap insofar as adolescents are concerned, thus focusing the researchers' attention on the topic and inviting scientists to prompt new experimental studies, as well as new types of technological tools to serve ID adolescents' needs and enhance their competencies in various life domains. Given the current digitalization of several life activities, we suggest that teaching methods should also move from traditional modes of education towards experience-oriented and cooperative teamwork-based education, which takes into account the features of the digital generation [40]. Today, augmented visual tools based on virtual reality are promoting experience-based learning processes and transforming the educational methods [41]. Because the learning processes have become strongly multidisciplinary and the digital space has replaced the typical educational environment, learning materials are available in a form that is independent from space and time [42]. In the CE generation's digital life, a 3D VR learning environment can have an encouraging effect on the students' learning processes [43]. However, we did not focus only on academic skills, but also – and especially – on competency enhancement of individuals with ID. This paper is intended to be of great use to all practitioners who deal with people with ID and their caregivers. Indeed, professionals and individuals close to these people should become aware of the power that contemporary technology has on competency enhancement and behavioral training of this population.

We believe that social integration and acceptance is to be fostered for individuals with ID and also for all other minority groups such as ethnic, religious, and social minorities, and also people who are gender diverse [44,45]. The latter, for instance, have been shown to encounter societal pressures that render them more vulnerable to negative health outcomes, which they need to face by mobilizing effective resilience factors to protect themselves from social stigma, discrimination, and victimization [46]. Our society needs to deeply acquire the capacity to be inclusive of all diversities to achieve substantial dignity. In other words, only if the diversity is accepted and achieves actual integration in our society, the latter can in fact be named as developed and mature.

V. Recommendations for future research and practice

The most relevant limitation of this review is that the vast majority of included studies (n = 15) have a very small sample size and no control group. Even though this makes their results questionable, we believe that they can nonetheless bring important and relevant insights into the usefulness of computerized tools in enhancing competencies in adolescents affected by ID. Given the small number of articles with experimental designs focusing on the effects of technology on cognitive and social competencies of adolescents with ID, our hope is that the present review will prompt future scholars to extend and deepen this field of research. Furthermore, ever new technological devices ought to be set up to help this population acquire extremely important cognitive and social competencies to be more independent and better integrated in society. In fact, computer-assisted programs ought to not only serve as instructional tools for academic content, but also – and perhaps more importantly – to provide individuals with ID with tools that might serve to improve and enhance their competencies, skills, and abilities in everyday life. Moreover, as the sample of the existing studies has been very small so far (see Table 1), an extension of the number of individuals who take part of similar studies should be considered. Finally, it appears that the socio-emotional component of everyday living has been widely underrated, and it is our hope that this aspect will be also deeply investigated in future researches [47].

Overall, in order to aid youth with ID in developing relevant competencies through the use of infocommunication systems and technological devices in general, more support needs to be provided, alongside adequate technological tools aimed at this specific population. The field of education appears as among the most promising to achieve this goal, given the importance of the learning process fostered in young individuals through the educational facilities they attend. Ultimately, competency enhancement in this population can be fostered through a responsible use of technological devices, which has the potential to render them less vulnerable and more autonomous in their daily life.

VI. Conclusions

Our systematic review highlighted how various competencies belonging to the social, adaptive, and cognitive domains can be fostered in young individuals with ID through the use of infocommunication systems and technological devices in general. Acquiring relevant life competencies can aid these individuals in achieving more autonomy in their daily life. Technological devices are becoming progressively prevalent in our society, often replacing face-to-face interactions and learning processes. Therefore, competency enhancement of this population through the use of technological devices can be a crucial step for our society to be authentically inclusive of the various types of diversity that are present within it. To this aim, the psychological empowerment of adaptive competencies in individuals with ID seems all the more fundamental today [48].

References

[1] American Psychiatric Association, "Diagnostic and Statistical Manual of Mental Disorders (5th Ed.)," Washington, DC: Author, 2013.

[2] S. Carvill, "Sensory impairments, intellectual disability and psychiatry," *Journal of Intellectual Disability Research*, 45, pp. 467–483, 2001, DOI: 10.1046/j.1365-2788.2001.00366.x.

[3] V. Bochicchio, C. Scandurra, R. Vitelli, P. Valerio, S. Dell'Orco, and N. M. Maldonato, "Epistemology of olfaction: Emotion, cognition, and decision making," *9th IEEE International Conference on Cognitive Infocommunications, CogInfoCom 2018 – Proceedings*, pp. 267–270, 2018, DOI: 10.1109/CogInfoCom.2018.8639940.

[4] J. C. Torrado, J. Gomez, and G. Montoro, "Hands-on experiences with assistive technologies for people with intellectual disabilities: Opportunities and challenges," *IEEE Access*, vol. 8, pp. 106 408–106 424, 2020, DOI: 10.1109/ACCESS.2020.3000095.

[5] K. M. Ayres, L. Mechling, and F. J. Sansosti, "The use of mobile technologies to assist with life skills/independence of students with moderate/severe intellectual disability and/or autism spectrum disorders: Considerations for the future of school psychology," *Psychology in the Schools*, vol. 50, pp. 259–271, 2013, DOI: 10.1002/pits.21673.

[6] T. Martins, V. Carvalho, F. Soares and M. F. Moreira, "Serious game as a tool to intellectual disabilities therapy: Total challenge," *2011 IEEE 1st International Conference on Serious Games and Applications for Health (SeGAH)*, Braga, Portugal, pp. 1–7, 2011. DOI: 10.1109/SeGAH.2011.6165444.

[7] S. Tsikinas and S. Xinogalos, "Designing effective serious games for people with intellectual disabilities," *2018 IEEE Global Engineering Education Conference (EDUCON)*, Santa Cruz de Tenerife, Spain, pp. 1896–1903, 2018, DOI: 10.1109/EDUCON.2018.8363467.

[8] L. C. Mechling, "Assistive technology as a self-management tool for prompting students with intellectual disabilities to initiate and complete daily tasks: A literature review," *Education and Training in Developmental Disabilities*, vol. 42, pp. 252–269, 2007.

[9] S. Ramdoss, R. Lang, and C. Fragale, "Use of computer-based interventions to promote daily living skills in individuals with intellectual disabilities: A systematic review," *Journal of Developmental and Physical Disabilities*, vol. 24, pp. 197–215, 2012, DOI: 10.1007/s10882-011-9259-8

[10] S. Snyder and H. Huber, "Computer assisted instruction to teach academic content to students with intellectual disability: A review of the literature," *American Journal on Intellectual and Developmental Disabilities*, vol. 124, no. 4, pp. 374–390, 2019, DOI: 10.1352/1944-7558-124.4.374

[11] D. M. Kagohara, L. van der Meer, S. Ramdoss, M. F. O'Reilly, G. E. Lancioni, T. N. Davis, and J. Sigafoos, "Using iPods and iPads in teaching programs for individuals with developmental disabilities: A systematic review," *Research in Developmental Disabilities*, vol. 34, pp. 147–156, 2013, DOI: 10.1016/j.ridd.2012.07.027.

[12] P. Baranyi, Á. Csapó "Definition and Synergies of Cognitive Infocommunications," *Acta Polytechnica Hungarica*, vol. 9, no. 1, pp. 67–83, 2012.

[13] P. Baranyi., Á. Csapó, and G. Sallai, Cognitive Infocommunications (CogInfoCom), Springer International Publishing, 2015.

[14] S. J. Gardner and P. S. Wolfe, "Teaching students with developmental disabilities daily living skills using video prompting with error correction," *Focus on Autism and Other Developmental Disabilities*, vol. 30, pp. 195–207, 2015, DOI: 10.1177/1088357614547810.

[15] L. C. Mechling, D. L. Gast, and S. Barthold, "Multimedia computer-based instruction to teach students with moderate intellectual disabilities to use a debit card to make purchases," *Exceptionality*, vol. 11, pp. 239–254, 2013, DOI: 10.1207/S15327035EX1104_4.

[16] D. L. Hansen and R. L. Morgan, "Teaching grocery store purchasing skills to students with intellectual disabilities using a computer-based instruction program," *Education and Training in Developmental Disabilities*, vol. 43, no. 4, pp. 431–442, 2008.

[17] M. Goo, W. Therrien, and Y. Hua, "Effects of computer-based video instruction on the acquisition and generalization of grocery purchasing skills for students with intellectual disability," *Education and Training in Autism and Developmental Disabilities*, vol. 51, no. 2, pp. 150–161, 2016.

[18] D. L. Hammond, A. D. Whatley, K. M. Ayres, and D. L. Gast, "Effectiveness of video modeling to teach iPod use to students with moderate intellectual disabilities," *Education and Training in Autism and Developmental Disabilities*, vol. 45, pp. 525–538, 2010.

[19] T. Taber-Doughty, E. C. Bouck, K. Tom, A. D. Jasper, S. M. Flanagan, and L. Bassette, "Video modeling and prompting: A comparison of two strategies for teaching cooking skills to students with mild intellectual disabilities," *Education and Training in Autism and Developmental Disabilities*, vol. 46, pp. 499–513, 2011.

[20] H. I. Cannella-Malone, J. E. Wheaton, P. Wu, C. A. Tullis, and J. H. Park, "Comparing the effects of video prompting with and without error correction on skill acquisition for students with intellectual disability," *Education and Training in Autism and Developmental Disabilities*, vol. 47, pp. 332–344, 2012.

[21] L. Palmqvist, H. Danielsson, A. Jönsson, and J. Rönnberg, "Feasibility of a tablet-based program for training everyday planning in adolescents with intellectual disabilities," *Journal of Cognitive Education and Psychology*, vol. 19, no. 2, pp. 172–186, 2020, DOI: 10.31234/osf.io/8xus2.

[22] M. J. Van der Molen, J. E. H. Van Luit, M. W. Van der Molen, I. Klugkist, M. J. Jongmans, "Effectiveness of a computerised working memory training in adolescents with mild to borderline intellectual disabilities," *Journal of Intellectual Disability Research*, vol. 54, no. 5, pp. 433–447, 2010, DOI: 10.1111/j.1365-2788.2010.01285.x.

[23] K. Sheriff and R. Boon, "Effects of computer-based graphic organizers to solve one-step word problems for middle school students with mild intellectual disability: A preliminary study," *Research in Developmental Disabilities*, vol. 35, pp. 1828–1837, 2014, DOI: 10.1016/j.ridd.2014.03.023.

[24] E. Bouck, L. Bassette, T. Taber-Doughty, S. Flanagan, and K. Szwed, "Pentop computers as tools for teaching multiplication to students with mild intellectual disabilities," *Education and Training in Developmental Disabilities*, vol. 44, pp. 367–380, 2009.

[25] C. Creech-Galloway, B. C. Collins, V. Knight, and M. Bausch, M., "Using a simultaneous prompting procedure with an iPad to teach the Pythagorean theorem to adolescents with moderate intellectual disability," *Research and Practice for Persons with Severe Disabilities*, vol. 38, pp. 222–232, 2013, DOI: 10.1177/154079691303800402.

[26] P. Baranyi and A. Gilányi, "Mathability: emulating and enhancing human mathematical capabilities," *4th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)* 2013, pp. 555–558, 2013.

[27] K. Chmielewska, "Educational Context of Mathability." *Acta Polytechnica Hungarica,* vol. 15, no. 5, 2018.

[28] K. Chmielewska and A. Gilányi, "Mathability and computer aided mathematical education," *2015 6th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, Gyor, Hungary, 2015, pp. 473–477, DOI: 10.1109/CogInfoCom.2015.7390639.

[29] K. Chmielewska, A. Gilányi and A. Łukasiewicz, "Mathability and mathematical cognition," *2016 7th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, Wroclaw, Poland, 2016, pp. 000 245–000 250, DOI: 10.1109/CogInfoCom.2016.7804556.

[30] K. Douglas, K. Ayres, J. Langone, V. Bell, and C. Meade, "Expanding literacy for learners with intellectual disabilities: The role of supported eText," *Journal of Special Education Technology*, vol. 24, 2009, DOI: 10.1177/016264340902400304.

[31] M. E. Hudson, "Using iPad-delivered instruction and self-monitoring to improve the early literacy skills of middle school nonreaders with developmental disabilities," *International Journal of Special Education*, vol. 34, no. 1, pp. 182–196, 2019.

[32] D. F. Cihak, K. Kessler, and P. A. Alberto, "Use of a handheld prompting system to transition independently through vocational tasks for students with moderate and severe intellectual disabilities," *Education and Training in Autism and Developmental Disabilities*, vol. 43, pp. 102–110, 2008.

[33] M. Kim, C. K. Blair, and K. Lim, "Using tablet assisted Social StoriesTM to improve classroom behavior for adolescents with intellectual disabilities," *Research in Developmental Disabilities*, vol. 35, pp. 2241–2251, 2014, DOI: 10.1016/j.ridd.2014.05.011.

[34] V. Bochicchio, N. M. Maldonato, P. Valerio, R. Vitelli, S. dell'Orco, and C. Scandurra, "A review on the effects of digital play on children's cognitive and socio-emotional development," *2018 9th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, pp. 000 261–000 266, 2018, DOI: 10.1109/CogInfoCom.2018.8639945.

[35] V. Bochicchio, K. Keith, I. Montero, C. Scandurra, and A. Winsler, A. "Digital media inhibit self-regulatory private speech use in preschool children: The 'digital bubble effect'," *Cognitive Development*, vol. 62, p. 101 180, 2022, DOI: 10.1016/j.cogdev.2022.101180.

[36] World Health Organization (2012). International Day of Persons with Disabilities, 3 December 2012. Assessed on April 7, 2023, from https://www.un.org/development/desa/disabilities/international-day-of-persons-with-disabilities-3-december.html.

[37] J. Borblik, O. Shabalina, M. Kultsova, A. Pidoprigora and R. Romanenko, "Assistive technology software for people with intellectual or development disabilities: Design of user interfaces for mobile applications," *2015 6th International Conference on Information, Intelligence, Systems and Applications (IISA)*, Corfu, Greece, pp. 1–6, 2015, DOI: 10.1109/IISA.2015.7387976.

[38] L. Cuascota, L. Guevara, R. Cueva, F. Tapia, and G. Guerrero, "Assistance application of people with cognitive disabilities in tasks for their social inclusion," *2019 14th Iberian Conference on Information Systems and Technologies (CISTI)*, Coimbra, Portugal, pp. 1–7, 2019, DOI: 10.23919/CISTI.2019.8760732.

[39] C. Peñaloza, J. Gutiérrez-Maldonado, M. Ferrer-García, A. Caqueo-Urizar, A. Reverter-Guimeso, Y. Macías-Cajal, D. Amela-Huemes, and S. Perales-Josa, "Cognitive mechanisms underlying Armoni: A computer-assisted cognitive training program for individuals with intellectual disabilities," *Anales de Psicologia*, 32, pp. 115–124, 2016, DOI: 10.6018/analesps.32.1.194511.

[40] V. Kövecses-Gősi, "Cooperative learning in VR environment," *Acta Polytechnica Hungarica*, vol. 15, no. 3, 2018, DOI: 10.12700/APH.15.3.2018.3.12

[41] G. Molnár and D. Sik, "Smart devices, smart environments, smart students: A review on educational opportunities in virtual and augmented reality learning environments," *2019 10th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, pp. 495–498, 2019, DOI: 10.1109/CogInfoCom47531.2019.9089984.

[42] I. Horváth, "Disruptive technologies in higher education," *2016 7th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, pp. 000 347–000 352, 2016, DOI: 10.3402/rlt.v20i0.19184

[43] I. Horváth, "Innovative engineering education in the cooperative VR environment," *2016 7th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, Wroclaw, Poland, pp. 000 359–000 364, 2016, DOI: 10.1109/CogInfoCom.2016.7804576.

[44] S. Mezzalira, C. Scandurra, F. Mezza, M. Miscioscia, M. Innamorati, and V. Bochicchio, "Gender felt pressure, affective domains, and mental health outcomes among transgender and gender diverse (TGD) children and adolescents: A systematic review with developmental and clinical implications," *International Journal of Environmental Research and Public Health*, vol. 20, no. 1, 2022, DOI: 10.3390/ijerph20010785.

[45] C. Scandurra, A. Carbone, R. Baiocco, S. Mezzalira, N. M. Maldonato, and V. Bochicchio, "Gender identity milestones, minority stress and mental health in three generational cohorts of Italian binary and nonbinary transgender people," *International Journal of Environmental Research and Public Health*, vol. 18, no. 17, 2021, DOI: 10.3390/ijerph18179057.

[46] F. Mezza, S. Mezzalira, R. Pizzo, N. M. Maldonato, V. Bochicchio, and C. Scandurra, "Minority stress and mental health in European transgender and gender diverse people: A systematic review of quantitative studies," *Clinical Psychology Review*, vol. 107, 102 358, 2024, DOI: 10.1016/j.cpr.2023.102358.

[47] S. Mezzalira, C. Scandurra, R. F. Pergola, N. M. Maldonato, I. Montero, and V. Bochicchio, "The psychological benefits and efficacy of computer-assisted training on competency enhancement in adults with intellectual disability. A systematic review," *Mediterranean Journal of Clinical Psychology*, vol. 9, no. 3, 2021, DOI: 10.13129/2282-1619/mjcp-3178.

[48] V. Bochicchio, A. L. Martinez-Pujalte Lopez, A. Hase, J. Albrecht, B. Costa, A. Devillé, R. Hensbergen, J. Sirfouq, and S. Mezzalira, "The psychological empowerment of adaptive competencies of individuals with Intellectual Disability: Literature-based rationale and guidelines for best training practices," *Life Span & Disability*, vol. 26, no. 1, pp. 129–157, 2023, DOI: 10.57643/lsadj.2023.26.1_06.

Selene Mezzalira

Cristiano Scandurra

Nelson Mauro Maldonato

Vincenzo Bochicchio

The responses to sad and happy infant faces are negatively associated with Maternal Emotional Availability

[1]*Carla Nasti, [1]Sonia La Resta, [2]Stefania Paternoster, [2]Silvia Perzolli, [2]Simona De Falco, and [1]Vincenzo Paolo Senese

***Abstract*—The pervasive presence of technology, including digital devices, intelligent networks, and online platforms, has given rise to new forms of human interaction. Therefore, it becomes crucial to understand how technological development influences profound aspects of human relationships, such as communication and the formation of social bonds, and consequently how it can positively integrate into human interactions while preserving fundamental elements such as emotional components and empathy. In this context, it is important to carefully examine the caregiver-child relationship. Several studies on the quality of this relationship have emphasized that it may depend on adult responses to salient infant cues considered at different processing levels. However, there are few studies that have investigated the predictive validity of the association between responses to infant cues and the quality of real caregiving behaviours. The aim of this study was to explore the association between responses to different infant cues, evaluated at different levels, and the quality of the caregiver-child relationship, measured in terms of emotional availability. 25 mother-child dyads participated in the study. Preliminarily mothers (27-50 years) were administered two implicit and two explicit measures (SC-IATs and Semantic Differentials) adapted to assess their responses to sad and happy infant faces and then, after a week, they were observed interacting with their child (aged 20-68 months) during 10 minutes of free play. The results confirmed a low consistency between responses to different stimuli and showed that implicit responses to sad (not happy) infant faces were positively associated with greater emotional availability, r=.37, p<.05. This study confirms the importance of considering both the emotional valence of infant stimuli and the processing level to assess in a valid way adult caregiving propensity.**

***Index Terms*—emotional availability, infant faces, caregiving, mother-child**

I. Introduction

In the contemporary era, the rapid pace of technological advancement has brought about a profound transformation in the way individuals relate to each other and their surrounding environment [1]. This metamorphosis is evident in various aspects of daily life, particularly in the realms of communication and social connections. The pervasive integration of technology, including digital devices, intelligent networks, and online platforms, has given rise to new modes of human interaction [2]. Scientific inquiry in this field is essential for understanding how technological evolution not only influences the practical aspects of daily existence but also the more intimate facets of human relationships, including empathy, communication, and the formation of social bonds. Within this framework, scientific research endeavors not only to elucidate the tangible repercussions of technology but also to unveil the emerging challenges and opportunities in relational dynamics [3] The overarching goal is to achieve a deep understanding of how new technologies can be seamlessly integrated into human interactions while concurrently safeguarding fundamental elements of human relationships, such as emotional dimensions and empathy. This convergence between technological progress and human interactions has emerged as a central theme of interest for researchers poised to outline the trajectory of an increasingly interconnected and technologically advanced society [4]

In this context, it is of relevance to thoroughly examine the relationship between caregiver and child. The connection between technological evolution and caregiving dynamics becomes crucial, as it can open new perspectives for understanding human interactions in the digital era. Indeed, the quality of caregiving in the earliest years of life is among of the most important factors that influence the child development [5,6]. According to Bornstein [7], caregiver-child interaction constitutes the privileged context for child growth [8]. In particular, researchers have argued that the response to infant's emotional and physical needs during the early years of life, and the ability to provide models of cognitive and behavioural self-regulation have an important role in child development [9,10] and can be evaluated as caregivers' emotional availability [11,12].

The conceptualization of emotional availability results from the integration of various definitions of the construct from different theoretical perspectives [13-15]. Currently, emotional availability (EA) refers to the quality of emotional exchanges between caregiver and child, and it focuses on the mutual accessibility of dyad members and their ability to read and respond appropriately to each other's communication [11]. In addition, Biringern and Easterbrooks [16] defined it as the ability of a dyad to share an emotional connection and to rejoice in a healthy and mutually fulfilling relationship. Due to this conceptualization of emotional availability [11,16] and the validation of the Emotional Availability Scale (EAS) [17], the construct has been widely used in research on the quality of the caregiver-child relationship [18].

[1] Department of Psychology, University of Campania "Luigi Vanvitelli", Caserta, Italy
* (E-mail: carla.nasti@unicampania.it)
[2] Department of Psychology and Cognitive Science, University of Trento, Trento, Italy

DOI: 10.36244/ICJ.2025.6.2

The EAS is an observation coding system developed to assess caregiver-child interaction, by taking into consideration both the caregiver's emotional availability toward the child and the child's emotional availability toward the caregiver [16]. The emotionally available interactive exchange is thus be punctuated by positive emotions, expressed through face, gestures and voice, and by the ability of the caregiver to modulate any negative emotional signals expressed by the child, and to consider child's emotional signals as indices for regulating his/her behaviour. For example, in choosing how to structure a game with the child, the emotionally available caregiver repeats an action that elicits amusement, proposes something new in case of signals of boredom, or slows down the pace of her proposals in the case of the child's lack of response; in this way he/she can be non-intrusive toward the child. Another key feature of the concept of emotional availability is the variability of emotions that the caregiver accommodates and the importance of conflict negotiation skills. How the caregiver responds to these emotions, returning them in an empathetic manner, helps the child to adjust and build an internal image in which negative experiences are integrated with positive ones [19]. The emotionally available caregiver is also able to tolerate and resolve moments of conflict and can resume an effectively pleasant rhythm in exchanges, without reacting with avoidance or impatience and hostility [20].

As a summary, according to the literature, EA is a dyadic and relational construct, and although caregiver and child are differentiated, the general EA of both members of the dyad is also considered [21,22]. The dyadic nature of the construct reflects the bidirectional nature of the relationship; in this view, in a caregiver-child interaction not only the caregiver can be more or less emotionally available to the child, but also the child, who can exhibit a personal tendency to be more or less emotionally responsive and engaging to the caregiver. Therefore, to understand the degree of EA in a dyad, it is essential to consider the behaviour of both members.

As a result, several studies that have investigate how EA is associated with child development, have shown that it can have positive effects on child's cognitive function, sleep wake rhythm regulation, and on the child's acquisition of sophisticated play skills [20,23,24]; moreover, EA seems to be associated with child attachment [25], emotional expression and regulation [26,27], language development [28], and child social competence [29]. Studies have also highlighted that an infant who experiences EA interactions manifests curiosity and explores the environment; positive emotions foster processes of infant's imitation and identification, and emotional exchanges develop infants' empathy and pro-social inclinations [21]. In contrast, a lack of emotional availability may be associated with coarctation of experience, excessive emotions, such as rejection and emotion avoidance [30,31]. This can happen either because the caregiver has a previous experience of distress that prevents from relating adequately to the child, or because the child has adjustment difficulties (e.g., with food or sleep, frequent crying) that could impair the caregiver's ability to care for him/her, hindering their relationship [32]. This can cause difficulties in emotional exchanges between caregiver and child and in caregiver's ability of decoding the infant signals, resulting in tense situations [17]. Therefore, the assessment of EA is important in cases where there are alterations and difficulties on the part of the caregiver to contribute to the construction of the relationship with the child, and to perform appropriate caregiver behaviours, as occurs in cases of maltreatment, separation, and foster care [33].

If from a side in the literature has been pointed out that the quality of the caregiver-child relationship has an impact on the child's development [5,6], on another side, several researchers are investigating the factors that influence the quality of the caregiver-child relationship [34] to understand what are the processes explaining why not all caregivers respond the same way to infant's need, and why some caregivers are more or less available than others [35]. According to the literature [34], caregiving behaviours are influenced by a complex interaction between context, child, and adult characteristics. Given that has been shown that human infants are characterized by certain morphological features that may elicit caregiving in their caregivers [36], some researchers [37,38] have focused their attention on how adults respond to infant cues by using different infant stimuli, such as neutral infant faces, infant faces with emotional valence or infant cries. These studies led to the development of the Parental Brain Model (PBM) [39] that tried to define the factors that can determine the caregiver's response from infant cues perception. Specifically, according to PBM [39], the caregiving response associated with the perception of infant cues is an innate process that evolved to ensure the survival of the offspring. According to PBM, infant cues are processed at different levels (i.e., reflexive, emotional, and cognitive), and the results of these parallel elaborations determine caregiving behaviour. As a consequence, if one is interested in assessing the caregiving propensity in a valid way, both the reflexive and less conscious levels and the more controlled and conscious levels should be considered. Moreover, given that one could consider different infant cues, it would be interesting to verify the extent to which there is consistency between different cues considering different levels of processing.

Studies that have investigated the response to different infant cues (i.e., infant faces and cries) have shown that the consistency between levels of processing is moderated by the type of cue [40-43]. This suggests that the theoretical model of responses to infant cues should also consider differences between infant cues. Indeed, there are studies that have shown that beyond infants' facial morphology, facial expressions can also influence the quality of caregivers' response [44-45]. Smiling children seems to receive more positive responses than crying children [46] and elicit more caring behaviours from caregivers [47]. Other studies have found that faces perceived as cute elicit tenderness in the caregiver by influencing the quality of caregiver-child interactions [48]. For example, Badr and Abdallah [49] found that infants who are perceived to be physically cuter receive better quality of care. In addition, other studies have also found that infants' facial expressions influence the caregiver's judgment of the child's abilities, and that children perceived as prettier are considered more capable and competent. Furthermore, prettier children seem to activate more the brain areas related to the reward circuitry [50].

Despite the scientific evidence reported by theoretical models [37,38], to our knowledge the majority of studies aimed at understanding the processes involved in caregiving behaviour by observing the response to infant cues have not taken these aspects into account. For example, there are still few studies that have investigated in an integrated manner the responses to infant cues by considering the different levels of processing (i.e., explicit and implicit) [40-43], or that have considered the differential effect of the emotional valence of infant cues (i.e., happy and sad faces) considering the different levels of processing [40,42,43]; moreover there are no studies that have investigated the specific association between responses to different infant cues, considering different levels of processing, on real caregiving behaviour.

Given the abovementioned considerations, the aim of this study was to compare maternal responses to infant faces while taking into account different levels of processing and stimuli with different emotional expression (happy and sad infant faces), and to examine the extent to which implicit and explicit responses to infant cues (happy and sad faces) are associated to the quality of the caregiver-child relationship, evaluated in terms of emotional availability. This could provide valuable information on understanding the processes underlying the caregiver-child relationship, to develop interventions aimed at improving the quality of care.

II. Method

A. Participants

A sample including 25 mother-child dyads was selected by convenience sampling. To be included in the study, mothers had to be of age, while children had to be aged between 28 and 60 months and had to show no general behavioural problems and have adaptive behaviour in a normal range. No other inclusion or exclusion criteria were considered. The participating mothers showed a mean age of 35.1 years (*SD* = 4.7; range 27-48) and at least a high school or university education level. The study was carried out in conformity with the Declaration of Helsinki and the local Ethics Committee requirements. All participants signed a written informed consent before starting data collection that also specified that the procedure would include a videotaping phase.

B. Procedure

The experimental session was divided in two phases temporally spaced. The first phase was carried out at distance. By means of *PsyToolkit*, an online protocol was administered to each mother [47]. The protocol included a socio- demographic information questionnaire, two Single Category Implicit Association Test (SC-IAT) [51] and two semantic differentials (SD) [52], adapted to collect respectively implicit and explicit responses to infant faces with different emotional valence (happy and sad faces). Measures were administered in a randomized order. The sessions lasted about 25 minutes. The second phase was carried out about a week later and was conducted in-person at the participants' homes. Mothers were required to play with her child for 10 minutes, in the way they usually do, by using a set of standardized toys consisting of a toy train, a tea set, a doll, a cover, a book, a telephone, and a set of interlocking toy bottles. The interactive session was videotaped. At the end of the observation, participants were de-briefed about the study and thanked.

C. Measures

Sociodemographics. A socio-demographic questionnaire was administered to collect maternal information, such as: age (expressed in years), gender, and educational levels.

Single Category Implicit Association Test (SC-IAT). To measure the valence of adults' implicit associations to infant stimuli (happy and sad faces), two versions of the Single Category Implicit Association Test (SC-IAT) were adapted and administered [51] The SC-IAT is a two-stage classification task. In each phase, stimuli of a single target category, in this study infant happy or sad faces [53], in combination with stimuli of two attribute categories, positive and negative words, are presented, one item at a time, in random order. Participants are asked to classify each item into the correct category as quickly as possible. In case of error, a red "X" appears in the centre of the screen, while to emphasize the speed of response, a 1500 ms response window following the onset of the stimulus is applied for each stimulus. In the first phase, pleasant words, and the target stimuli are classified by using the same response key, while unpleasant words are classified using a different key (positive condition). In the second phase, unpleasant words, and the target stimuli are classified using the same response key, while pleasant words are classified using a different key (negative condition). The SC-IAT score is derived by comparing the latencies of responses in the two classification phases. If participants are faster in classifying stimuli in the positive condition than in the negative condition, they are considered to have an implicit positive association toward the target stimuli. If the opposite is true, a negative implicit association is attributed. For each test (sad faces and happy faces), the SC-IAT score was calculated by dividing the difference between the mean RTs of the two classification conditions by the standard deviation of the latencies of the two phases (positive and negative) [54]. Consequently, scores around 0 indicate no IAT effect; absolute values from 0.2 to 0.3 indicate a "slight" effect, values around 0.5 a "medium" effect, and values from 0.8 to infinity a "large" effect. The two tests showed adequate reliability (αs >.80).

Semantic Differential. To assess adults' explicit attitudes toward child cues (happy and sad faces), two semantic differentials (SD) [52] were adapted and administered to mothers. For each SD, participants rated the target stimuli, sad or happy infant faces (the same stimuli used in the SC-IAT), using six bipolar adjectives pairs (annoying-adorable; ugly-beautiful; hell-paradise; unpleasant-pleasant; joy-painful; happy- sad; gift-disaster; friend-enemy; hate-love). Responses were collected on a seven-point scale. A total mean score was computed for each SD, with higher values indicating a more positive evaluation of the target stimuli. The two SDs showed adequate reliability (αs >.80).

Emotion Availability Scale. The (EAS) [17] is an observational grid that can be applied to videotaped material to measure the emotion availability of a dyad. The scale is divided into six sub-scales, four related to the caregiver and two related to the child: (a) *sensitivity*, indicates the caregiver's ability to establish and preserve a positive, healthy emotional relationship with the child; (b) *structuring,* indicates the caregiver's ability to offer support, backing and stimulation in the child's exploration and activities, while respecting the child's autonomy and cues; (c) *non-intrusiveness*, that is related to the caregiver's ability to

be available without encroaching on the child's autonomy; (d) *non-hostility*, indicates the caregiver's ability to pose to the child in affectionate, warm, pleasant, and sensitive ways; (e) *responsiveness*, indicates the child's ability, desire, and emotional inclination to interact with his or her caregiver, following an explicit invitation; (f) *involvement*, indicates the child's ability to engage and seek out the caregiver in play and activity. For each sub-scale, the dimension is scored using a 7-point Likert from "1" (lowest score) to "7" (highest score). In this study, the entire play session was considered for coding the observed emotional availability [17], and for each dyad, both a score for each subscale and a total mean score were calculated. Two independent judges have completed the observation grids showing adequate inter-rater reliability for all scales (ICC > .80).

D. ANALYTIC PLAN

To analyse the results, descriptive statistics were calculated first and then two correlation analyses were performed. A first analysis was conducted investigating the association between the responses observed at the different processing levels (implicit and explicit) and related to the different type of stimuli considered (sad and happy faces), to evaluate their consistency. Subsequently, to verify the relationship between the responses to the infant stimuli and the quality of the mother-child interaction, the responses to the different infant stimuli, recorded in the different processing levels, and the EAS scale indices obtained from the analyses of the observations were correlated. An alpha value of .05 was set for all analyses.

III. RESULTS

Descriptive analysis showed that happy faces had more positive responses than sad faces, and this was observed regardless of the level of processing considered. In both cases, the difference was significant, *t*s > 2.1, *p*s < .023 (see Table 1).

TABLE I
DESCRIPTIVE STATISTICS OF VARIABLES

Measure	M	SD
SD Happy	6.0	1.1
SD Sad	3.1	1.0
SC-IAT Happy	0.08	0.64
SC-IAT Sad	-0.46	0.92
EAS Adult Sensitiviy	5.3	0.8
EAS Adult Structuring	5.2	0.9
EAS Adult Non-Intrusiveness	5.3	0.7
EAS Adult Non-Hostility	6.2	0.8
EAS Child Responsiveness	4.9	1.1
EAS Child Involvement	4.6	1.3
EAS Total Score	5.2	0.8

SC-IAT=Single Category Implicit Association Test; SD= Semantical Differential; Emotional Availability=Emotional Availability Scales; EAS Adult Sensitivity = Emotional Availability Scales (Adult Sensitivity Subscale); EAS Adult Structuring = Emotional Availability Scales (Adult Structuring Subscale); EAS Adult Non-Intrusiveness= Emotional Availability Scales (Adult Non Intrusiveness Subscale);EAS Adult Non-Hostility = Emotional Availability Scales (Adult Non Hostility Subscale); EAS Child Responsiveness= Emotional Availability Scales (Child Responsiveness Subscale); EAS Involvement= Emotional Availability Scales (Child Involvement Subscale)

Furthermore, the data showed a ceiling effect for explicit responses to happy faces (see Table 2). In the present study, our aim was to assess the consistency between explicit responses to sad and happy faces. The statistical procedure was applied using the Pearson correlation coefficient *(r*), allowing us to evaluate the strength and direction of associations between the variables of interest. The correlation analysis investigating the consistency between the responses to infant cues showed that the explicit response to sad faces and happy faces correlated negatively and significantly, $r = -.40$, $p = .024$, and that the explicit and implicit response to sad faces correlated negatively and significantly, $r = -.34$, $p = 049$ (see Table 1). No other significant associations were observed, although, in the case of the two implicit responses, an association approximating to the significance was observed. These results provide a more detailed insight into the dynamics of responses to infant cues, highlighting the complexity of interactions between explicit and implicit responses to different emotional expressions. This opens the door to further reflections on the intricate nature of human responses to infant facial expressions.

TABLE II
PEARSON CORRELATION BETWEEN THE RESPONSES TO INFANT FACES AS A FUNCTION OF LEVELS OF PROCESSING AND TYPE OF STIMULUS

Measure	1	2	3
1. SD Happy	-		
2. SD Sad	**-.40***	-	
3. SC-IAT Happy	-.08	.15	-
4. SC-IAT Sad	-.02	**-.34***	-.32

SC-IAT=Single Category Implicit Association Test; SD= Semantical Differential.
*p<.05

Descriptive analyses have shown that, in general, dyads are characterized by a "moderate level" of emotional availability, i.e. good interaction patterns (see Table 1). The correlation analysis investigating the association between responses to infant cues and the quality of caregiving showed that only implicit responses to sad faces had a significant association with the observed emotional availability of the dyads. The statistical procedure was applied using the Pearson correlation coefficient *(r*), allowing us to evaluate the strength and direction of associations between the variables of interest. In particular, the IAT score related to the sad faces showed a positive association with the caregiver's non-hostility score, $r = .39$, $p = .027$, and with the dyad total emotional availability score, $r = .37$, $p = .033$ (see Table 3). No other significant associations were observed, although, in the case of the implicit responses to sad faces, other associations approximated to the significance, i.e., the mother's sensitivity and the child's involvement. These results clearly indicate that implicit responses to sad faces are crucial for understanding the quality of caregiving in caregiver-child dynamics. This evidence underscores the importance of deepening the understanding of these associations to develop targeted strategies aimed at improving emotional interaction in infant care contexts.

TABLE III
PEARSON CORRELATION BETWEEN THE RESPONSES TO EMOTIONAL AVAILABILITY AS A FUNCTION OF LEVELS OF PROCESSING AND TYPE OF STIMULUS

	SD		SC-IAT	
EAS	**Happy**	**Sad**	**Happy**	**Sad**
Adult				
Sensitivity	.07	-.14	-.19	.33
Structuring	-.06	-.08	-.21	.27
Non-Intrusiveness	-.31	.09	.11	.22
Non-Hostility	.03	-.22	-.07	**.39***
Child				
Responsiveness	-24	.05	-.08	.28
Involvement	-.17	.06	-.18	.30
Total score	-.14	-.05	-.13	**.37***

SC-IAT=Single Category Implicit Association Test; SD= Semantical Differential; Emotional Availability=Emotional Availability Scales; EAS Adult Sensitivity = Emotional Availability Scales (Adult Sensitivity Subscale); EAS Adult Structuring = Emotional Availability Scales (Adult Structuring Subscale); EAS Adult Non-Intrusiveness= Emotional Availability Scales (Adult Non Intrusiveness Subscale);EAS Adult Non-Hostility = Emotional Availability Scales (Adult Non Hostility Subscale); EAS Child Responsiveness= Emotional Availability Scales (Child Responsiveness Subscale); EAS Involvement= Emotional Availability Scales (Child Involvement Subscale)

*p<.05

IV. DISCUSSION

The aim of the present study was to investigate the ways in which mothers process different infant cues and to what extent the responses to infant cues were associated with caregiving behaviour, in terms of emotional availability. To this aim, maternal responses to infant cues characterized by different emotional expressions (happy and sad) and observed at different levels of processing (explicit and implicit) were considered. Subsequently, the predictive validity of these measures was tested by assessing emotional availability during mother-child interactions. The results confirmed that although both implicit and explicit responses towards infant happy faces are more positive than responses to sad faces [46-50], there is substantial independence between the responses, both when considering different stimuli and when considering different levels of processing [40-43]. Moreover, results showed, that only implicit responses to sad faces were significantly and positively associated with the quality of mother-child interaction, that is with the caregiver's "non-hostility" subscale and the total emotional availability score of the dyad. No positive associations were observed with either explicit or implicit responses to happy faces. This latter result could be explained by the fact that emotionally available mothers are more capable to tolerate, accept and respond with less avoidance, impatience, or hostility to negative infant signals [20], thus favouring the learning of emotional expression and regulation [26,27].

V. CONCLUSIONS

In summary, while these results are in line with the literature, confirming that different childhood stimuli lead to different adult responses [39], they also show for the first time that not all responses to different childhood stimuli, or at different levels of processing, are equivalent or show the same association with actual behavior.

Although this study has the merit of having (a) investigated the consistency between implicit and explicit responses to different infant cues (happy and sad faces), and (b) investigated if explicit and implicit responses to infant faces (happy and sad) and different level of processing (implicit and explicit) were associated with caregiving behavior evaluated in terms of emotional availability, there are also some limitations that should be mentioned. First, the sample size is small, and this poses a threat to the statistical validity and generalisability of the results. Therefore, further studies are needed to verify the validity of these results by enlarging the sample. Second, the sample included only mothers and did not include fathers. Indeed, understanding the potential contribution of fathers represents a next step in the expansion of research on caregiving behaviour, as the quality of paternal involvement with children appears to be positively correlated with the developmental outcomes in children [54,55]. Data showed that the active involvement of fathers in interventions is particularly important for several benefits, including improving the quality of co-parenting and reducing parenting stress [56]. Future studies should replicate the study considering not only mothers but also the fathers. Finally, we must acknowledge that a substantial limitation of our investigation is the issue of low construct validity. This poses a significant challenge, and our study could benefit from future research efforts that delve more deeply into the complex nature of maternal responses to infant cues.

In conclusion, while recognizing these limitations, we believe that our analysis provides a foundation for further reflection and theoretical development. We are aware of the need to deepen the understanding of this complex phenomenon and hope that our work can serve as a stepping stone for future research that explores more comprehensively the relationship between maternal responses and the quality of caregiving in the context of mother-child interactions. In addition, the study highlights the importance of a multimodal approach in evaluating caregiving behavior. Based on the observed results, the assessment of adults' implicit associations to different infant cues, in addition to explicit measures, should be included in screening protocols to prevent negative outcomes and plan programs.

REFERENCES

[1] Onyeator, I., & Okpara, N. (2019). Human communication in a digital age: Perspectives on interpersonal communication in the family. *New Media and Mass Communication*, 78(1), 35–45. DOI: 10.7176/NMMC

[2] Bayer, J. B., Triệu, P., & Ellison, N. B. (2020). Social media elements, ecologies, and effects. *Annual review of psychology*, 71, 471–497.

[3] Sarigiani, P., Trumbell, J., & Camarena, P. (2013). Electronic communications technologies and the transition to college: Links to parent-child attachment and adjustment. *Journal of The First-Year Experience & Students in Transition*, 25(1), 35–60.

[4] Dwivedi, Y. K., Hughes, L., Baabdullah, A. M., Ribeiro-Navarrete, S., Giannakis, M., Al-Debei, M. M., ... & Wamba, S. F. (2022). Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management*, 66, 102542.

[5] Collins, W. A., Maccoby, E. E., Steinberg, L., Hetherington, E. M., & Bornstein, M. H. (2000). Contemporary research on parenting: *The case for nature and nurture*. *American Psychologist*, 55(2), 218–232. DOI: 10.1037/0003-066X.55.2.218

[6] DePasquale, C. E. (2020). A systematic review of caregiver–child physiological synchrony across systems: Associations with behavior and child functioning. *Development and Psychopathology*, 32 (5), 1754–1777. DOI: 10.1017/S0954579420001236

[7] Bornstein, M. H. (2016). Determinants of parenting. In D. Cicchetti (Ed.), *Developmental psychopathology: Risk, resilience, and intervention*, 180–270. John Wiley & Sons, Inc.. DOI: 10.1002/9781119125556.devpsy405

[8] Bornstein M.H. (Ed., 2002). Handbook of parenting: Vol. 1. Children and parenting (2nd ed.) Emmett, S. (2023). Assessing Young Children's Emotional Well-Being: Enacting a Strength-Based Approach in Early Childhood Education. In *Assessment and Data Systems in Early Childhood Settings: Theory and Practice* (pp. 201–221). Singapore: Springer Nature Singapore.

[9] Emmett, S. (2023). Assessing Young Children's Emotional Well-Being: Enacting a Strength-Based Approach in Early Childhood Education. In *Assessment and Data Systems in Early Childhood Settings: Theory and Practice* (pp. 201–221). Singapore: Springer Nature Singapore.

[10] Murray, L., Fiori-Cowley, A., Hooper, R., & Cooper, P. (1996). The impact of postnatal depression and associated adversity on early mother-infant interactions and later infant outcome. *Child development*, 67(5), 2512–2526

[11] Biringen, Z. (2000). Emotional availability: Conceptualization and research findings. *American Journal of Orthopsychiatry*, 70 (1), 104–114. **DOI**: 10.1037/h0087711

[12] Emde, R. N. (2000). Next steps in emotional availability research. *Attachment & Human Development*, 2(2), 242–248. **DOI**: 10.1080/14616730050085590

[13] Bowlby, J. (1969). *Attachment and Loss, Vol. 1*, Attachment. New York: Basic Books.

[14] Ainsworth, M. D. S., Blehar, M. C., & Waters, E. (1979). Patterns of attachment: *A Psychological Study Of The Strange Situation*. Research Gate, 23(1), 1–416. **DOI**: 10.4324/9781315802428

[15] Mahler, M.S. (1974). Symbiosis and Individuation: the psychological birth of the human infant. *The Psychoanalytic Study of the Child*, 29 (1), 89–106. **DOI**: 10.1177/000306516701500401

[16] Biringen, Z., & Easterbrooks, M. A. (2012). Emotional availability: Concept, research, and window on developmental psychopathology. *Development and psychopathology*, 24 (1), 1–8. **DOI**: 10.1017/S0954579411000617

[17] Biringen, Z. (2008). *Emotional Availability Scales (4th ed.)*. International Center for Excellence in Emotional Availability.

[18] Perzolli, S., Bertamini, G., de Falco, S., Venuti, P., & Bentenuto, A. (2020). Emotional Availability and Play in Mother-Child Dyads with ASD: Changes during a Parental Based Intervention. *Brain sciences*, 10(12), 904. **DOI**: 10.3390/brainsci10120904

[19] Haft, W. L., & Slade, A. (1989). Affect attunement and maternal attachment: A pilot study. *Infant Mental Health Journal*, 10(3), 157–172. **DOI**: 10.1002/1097-0355(198923)10:3<157::AID-IMHJ2280100304>3.0.CO;2-3

[20] Venuti, P., De Falco, S., Giusti, Z., & Bornstein, M. H. (2008). Play and emotional availability in young children with Down syndrome. *Infant Mental Health Journal: Official Publication of The World Association for Infant Mental Health*, 29(2), 133–152. **DOI**: 10.1002/imhj.20168

[21] Biringen, Z., Derscheid, D., Vliegen, N., Closson, L., & Easterbrooks, M. A. (2014). Emotional availability (EA): Theoretical background, empirical research using the EA Scales, and clinical applications. *Developmental Review*, 34(2), 114–167. **DOI**: 10.1016/j.dr.2014.01.002

[22] Garrido-Vásquez, P., Pell, M. D., Paulmann, S., & Kotz, S. A. (2018). Dynamic facial expressions prime the processing of emotional prosody. *Frontiers in human neuroscience*, 12, 244. **DOI**: 10.3389/fnhum.2018.00244

[23] Pressman, L. J., Pipp-Siegel, S., Yoshinaga-Itano, C., Kubicek, L., & Emde, R. N. (1999). A comparison of the links between emotional availability and language gain in young children with and without hearing loss. Volta Review, 100(5), 251–77.

[24] Sagi, A., Koren-Karie, N., Ziv, Y., Joels, T., & Gini, M. (1998). *Shedding further light on the NICHD study of early child care: The Israeli case*. *Discussion session presented in the International Conference on Infant Studies*, Altlanta, GA (April).

[25] Easterbrooks, M. A., Bureau, J. F., & Lyons-Ruth, K. (2012). Developmental correlates and predictors of emotional availability in mother–child interaction: A longitudinal study from infancy to middle childhood. *Development and psychopathology*, 24(1), 65–78. **DOI**: 10.1017/S0954579411000666

[26] Little, C., & Carter, A. S. (2005). Negative emotional reactivity and regulation in 12-month-olds following emotional challenge: Contributions of maternal–infant emotional availability in a low-income sample. *Infant Mental Health Journal: Official Publication of The World Association for Infant Mental Health*, 26(4), 354–368. **DOI**: 10.1002/imhj.20055

[27] Martins, E. C., Soares, I., Martins, C., Tereno, S., & Osório, A. (2012). Can we identify emotion over-regulation in infancy? Associations with avoidant attachment, dyadic emotional interaction and temperament. *Infant and Child Development*, 21(6), 579–595. **DOI**: 10.1002/icd.1760

[28] Lovas, G. S. (2002). *Early gender development in the context of parent/toddler interactions: Emotional availability and language development*. University of California, Davis.

[29] Howes, C., & Obregon, N. B. (2009). Emotional availability in Mexican-heritage low-income mothers and children: Infancy through preschool. Parenting. *Science and Practice*, 9(3-4), 260–276. **DOI**: 10.1080/15295190902844589

[30] Moehler, E., Biringen, Z., & Poustka, L. (2007). Emotional availability in a sample of mothers with a history of abuse. *American Journal of Orthopsychiatry*, 77(4), 624–628. **DOI**: 10.1037/0002-9432.77.4.624

[31] AlOdhayani, A., Watson, W. J., & Watson, L. (2013). Behavioural consequences of child abuse. *Canadian family physician*, 59(8), 831–836.

[32] Sharma, S. (2016). Behavioural consequences of child abuse. *Institutionalised Children Explorations and Beyond*, 3(1), 66–76. **DOI**: 10.1177/2349301120160107

[33] Saunders, H., Kraus, A., Barone, L., & Biringen, Z. (2015). Emotional availability: theory, research, and intervention. *Frontiers in psychology*, 6, 1069. **DOI**: 10.3389/fpsyg.2015.01069

[34] Taraban, L., & Shaw, D. S. (2018). Parenting in context: Revisiting Belsky's classic process of parenting model in early childhood. *Developmental Review*, 48, 55–81. **DOI**: 10.1016/j.dr.2018.03.006

[35] Zhu, X., Wang, L., Cao, A., Zhang, Y., & Qiu, J. (2020). Personality traits and negative affect mediate the relationship between cortical thickness of super frontal cortex and aggressive behaviour. *Neuroscience letters*, 718, 134728. **DOI**: 10.1016/j.neulet.2019.134728

[36] Lorenz, K. (1971). *Studies in Animal and Human Behavior*. Cambridge, MA: Harvard Univ Press

[37] Feldman, R. (2015). The adaptive human parental brain: implications for children's social development. *Trends in neurosciences*, 38(6), 387–399. **DOI**: 10.1016/j.tins.2015.04.004

[38] Young, K. S., Parsons, C. E., Jegindoe-Elmholdt, E. M., Woolrich, M. W., van Hartevelt, T. J., Stevner, A. B., et al. (2016). Evidence for a caregiving instinct: rapid differentiation of infant from adult vocalizations using magnetoencephalography. *Cerebral Cortex*, 26(3), 1309–1321. **DOI**: 10.1093/cercor/bhv306

[39] Swain, J. E., Kim, P., Spice, J., Ho, S. S., Dayton, C. J., Elmadih, A., & Abel, K. M. (2014). Approaching the biology of human parental attachment: brain imaging, oxytocin and coordinated assessments of mothers and fathers. *Brain Research*, 1580, 78–101. **DOI**: 10.1016/j.brainres.2014.03.007.

[40] Senese, V.P., Azhari, A., & Cataldo, I. (2019). A Multi-System Psycho-Biological Approach to the Understanding of Parental Dispositions. *Parenting. Science and Practice*, 19(1-2), 164–167. **DOI**: /10.1080/15295192.2019.1556027

[41] Senese, V.P, De Falco, S., Bornstein, M.H., Caria, A., Buffolino, S., Venuti, P. (2013). Human Infant Faces Provoke Implicit Positive Affective Responses in Parents and Non-Parents Alike. *PlosOne,* 8(11), e80379. **DOI**: 10.1371/journal.pone.0080379

[42] Senese, V. P., Miranda, M. C., De Falco, S., Venuti, P., & Bornstein, M. H. (2018). How Becoming a Mother Shapes Implicit and Explicit Responses to Infant Cues. *Developmental Psychobiology*. 00, 1–13. **DOI**: 10.1002/dev.21772

[43] Senese, V. P., Nasti, C., Pezzella, M., Marcone, R., & Conson, M. (2021). Adults responses to infant faces and cries: consistency between explicit and implicit measures. In: Esposito A., Faundez-Zanuy M., Morabito F., Pasero E. (eds) *Neural Approaches to Dynamics of Signal Exchanges*. *Smart Innovation, Systems and Technologies*, vol 152. Springer, Singapore. **DOI**: 10.1007/978-981-15-5093-5_42

[44] Takamatsu, R., Kusumi, T., & Nittono, H. (2023). Personality descriptions influence perceived cuteness of children and nurturing motivation toward them. *PloS one*, 18(1), e0279985. DOI: 10.1371/journal.pone.0279985

[45] Esposito, A. Esposito, A. M., Cirillo, I., Panfilo, L., Scibelli, F., Maldonato, M., & Vogel, C. (2017, September). Differences between hearing and deaf subjects in decoding foreign emotional faces. In *2017 8th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)* (pp. 000 175–000 180). IEEE.

[46] Mizugaki S., Maehara, Y., Okanoya, K., & Myowa-Yamakoshi, M. (2015). The power of an infant's smile: maternal physiological responses to infant emotional expressions. *PloS One*, 10(6), e0129672. DOI: 10.1371/journal.pone.0129672

[47] Lobmaier J. S., Sprengelmeyer, R., Wiffen, B., & Perrett, D. I. (2010). Female and male responses to cuteness, age and emotion in infant faces. *Evolution and Human Behavior*, 31(1), 16–21. DOI: 10.1016/j.evolhumbehav.2009.05.004

[48] Franklin, P., Volk, A. A., & Wong, I. (2018). Are newborns' faces less appealing?. *Evolution and Human Behavior*, 39(3), 269–276. DOI: 10.1016/j.evolhumbehav.2018.01.003

[49] Badr, L. K., & Abdallah, B. (2001). Physical attractiveness of premature infants affects outcome at discharge from the NICU. *Infant Behavior and Development*, 24, 129–133. DOI: 10.1016/S0163-6383(01)00068-6

[50] Hahn, A. C., DeBruine, L. M., Fisher, C. I., & Jones, B. C. (2015). The reward value of infant facial cuteness tracks within-subject changes in women's salivary testosterone. *Hormones and Behavior*, 67, 54–59. DOI: 10.1016/j.yhbeh.2014.11.010

[51] Greenwald A. G., Nosek, B. A., Banaji, M. R. (2003). Understanding and using the implicit association test: I. An improved scoring algorithm. *J. Pers. Soc. Psychol.* 85, 197–216.

[52] Osgood, C. E., Suci, G., & Tannenbaum, P. (1957). The measurement of meaning. Urbana, IL: University of Illinois Press

[53] Maack, J. K., Bohne, A., Nordahl, D., Livsdatter, L., Lindahl, Å. A., Øvervoll, M., Wang, C. E., & Pfuhl, G. (2017). The Tromso Infant Faces Database (TIF): Development, Validation and Application to Assess Parenting Experience on Clarity and Intensity Ratings. *Frontiers in psychology*, 8, 409. DOI: 10.3389/fpsyg.2017.00409

[54] Aytuglu, A., & Brown, G. L. (2022). Pleasure in parenting as a mediator between fathers' attachment representations and paternal sensitivity. *Journal of Family Psychology,* 36(3), 427–437. DOI: 10.1037/fam0000905

[55] Pancsofar, N., Vernon-Feagans, L., & Family Life Project Investigators. (2010). Fathers' early contributions to children's language development in families from low-income rural communities. *Early childhood research quarterly*, 25(4), 450-463. DOI: 10.1016/j.ecresq.2010.02.001

[56] Bergmann, S., & Klein, A. M. (2020). Fathers' emotional availability with their children: Determinants and consequences. Handbook of Fathers and *Child Development: Prenatal to Preschool*, 315–337. DOI: 10.1007/978-3-030-51027-5_20

Carla Nasti, P.hD is currently a Postdoctoral Researcher at the Department of Educational, Psychological and Communication Sciences at the University of Suor Orsola Benincasa. She is also a collaborator at the Psychometric Laboratory of the Department of Psychology at the University of Campania Luigi Vanvitelli. Carla is a psychologist and a cognitive-behavioural psychotherapist. Her research focuses on parenting and psychological well-being across the lifespan.

Sonia La Resta is Psychologist and Neuro and Psychomotor Therapist of developmental age (TNPEE). She is specialized in psychodiagnosis and parent-coaching. Specifically, she deals with the evaluation and rehabilitation of subjects with neurodevelopmental disorders. She is is also a collaborator at Psychometric Laboratory of Department of Psychology at the University of Campania "Luigi Vanvitelli".

Stefania Paternoster is Psychologist with a special interest in neurodevelopmental disorders and neuropsychology. During her professional internship, she acquired knowledge and skills related to evaluation and intervention in autism spectrum disorder. Currently involved in supporting children with neurodevelopmental disorders in school activities and promoting inclusion in the social context. She collaborates with the Laboratory of Observation, Diagnosis and Training from the Department of Psychology and Cognitive Science of the University of Trento.

Silvia Perzolli, P.hD is an Assistant Professor in Developmental and Educational Psychology at the Department of Psychology and Cognitive Science, University of Trento. Her research focuses on child development in typical and atypical contexts, with a specific interest in autism spectrum conditions and interventions with parent involvement to support child development and family well-being. She also works on learning processes and innovation in educational contexts, including both school and higher education. She is currently the Educational Portfolio Coordinator for ECIU University (European Consortium of Innovative Universities).

Simona De Falco, P.hD is Full Professor of Psychodynamics at the University of Trento. She has a strong track record in the study of parenting and child social-affective behaviour in typical and atypical development. She leads the research team of the ODFLab of the University of Trento, a clinical centre addressing psychological wellbeing across the life-span. She has authored/co-authored more than 40 peer-reviewed journal articles and book chapters.

Vincenzo Paolo Senese, P.hD is Associate Professor in Psychometrics at the University of Campania Luigi Vanvitelli where is the head of the Psychometric Laboratory. His main research interests are on the application of measurement models in the development of tests and questionnaires, with special attention to implicit and automatic processes on parental behaviour. He is also an International Affiliate of the Rohner Center for the Study of Interpersonal Acceptance & Rejection and has been elected as President of the International Society for Inter-Personal Acceptance Rejection (ISIPAR) 2022-2024.

Does parenting affect recognition of emotions conveyed by children?

Terry Amorese[1], Marialucia Cuciniello[1], Claudia Greco, Gennaro Cordasco, and Anna Esposito[1]

***Abstract*—The present work investigates those factors affecting the way people recognize face, gestures, and more specifically emotional expressions. To this aim, a study is proposed, in which were involved sixty participants split in two groups (parents and childless subjects). Participants were required to label pictures of male and female children belonging to different ethnicity displaying static expressions of anger, disgust, fear, happiness, sadness, surprise, and neutrality. Results showed that the gender and the ethnicity of the stimulus clearly affected results; moreover, differences were observed between parents and childless participants concerning percentages of emotions recognition accuracy.**

***Index Terms*—emotion processing, face recognition**

I. Introduction

Information and Communication Technologies (ICTs) find a large number of applications in different fields such as psychology, education, and rehabilitation; moreover, ICTs and humans' cognitive processes are deeply linked and mutually affects each other. Among humans' cognitive processes emotions play a significant role. A core aspect, which also represent a fundamental component of what is defined "emotional intelligence", is face and gesture recognition. However, emotion recognition processes are complex, and may be affected by numerous factors, both related to "who" is recognizing an emotional expression and to "who/what" is the subject of the recognition process.

Several features of the person who is encoding a facial expression affect this process, among these, subject's age, aging [1][2][3], and gender, as well [4][5][6]. In addition, even features of the showed face influence the decoding process, as the typology [7], the age [8][9] and the gender [10]. Concerning the differences between men and women in the interpretation of emotions some studies emphasized women's greater ability to accurately detect emotional expression compared to men [4]. Other studies showed that the gender effect may be related to factors such as the stimulus intensity, emphasizing that women have greater accuracy especially for subtle expressions of emotion [11]. Previous studies highlighted an effect of the modality in which the stimulus is presented and the associated sensory channel, in fact women are more accurate than men when interpreting in particular emotional prosody [6].

As regards as the effect on emotion recognition of both the gender of the encoder and of the stimulus, some have proposed an effect known as "Own Gender Bias" [12], which suggests that people decode facial expressions of the same gender faster and more accurately compared to faces of the opposite sex [13].

Another factor of interest is the effect of faces' ethnicity on emotion recognition. In literature a well-known phenomenon is the Own Race Bias (ORB) [14], according to which faces belonging to unfamiliar racial groups are worse decoded compared to own-race faces. The Own race bias is often explained through the "contact hypothesis" [15] according to which the amount of contact that an individual has with another race is positively correlated with the recognition accuracy for faces of that race. Ethnicity is a key factor in the field of emotion recognition, even considering that people are ethically biased when deciphering emotions [16][17][18].

An interesting aspect in relation to the person decoding a face that in our knowledge has not been investigated in depth, concerns whether the continuous exposure to certain facial features could somehow facilitate and makes people more capable to recognize the expressions conveyed by that type of face, more specifically we refer to differences between parents and childless people in the ability to code facial expressions of children.

Considered the aforementioned factors and their effects on emotion recognition processes, and the weight of emotions within ICT field, a study is proposed. Static pictures depicting children, belonging to different ethnicity were exploited for this research; two group of participants (parents and childless) were required to recognize facial expressions of anger, disgust, fear, happiness, sadness, surprise, and neutrality. The presented investigation aims at assessing the effect of participants' parenthood on their capability to decode children' static facial expressions and the effect of stimuli's gender and ethnicity (European, African American, Latino American, and Asian) on participants' ability to decode facial emotional expressions.

[1] Department of Psychology, University of Campania "Luigi Vanvitelli", Caserta, Italy

E-mail: terry.amorese@unicampania.it, marialucia.cuciniello@unicampania.it, claudia.greco@unipv.it, gcordasco@unisa.it, anna.esposito@unicampania.it

DOI: 10.36244/ICJ.2025.6.3

II. Materials and Methodology

A. Participants

The study involved 60 healthy subjects aged between 20-50 years, split into two groups: a group of 30 childless participants (mean age=31.53; SD= ±0.9, 17 females) and a group of 30 parents (mean age=37.53; SD= ±8.5, 19 females). Participants were administered an emotion decoding task, more in detail a recognition task of children static emotional faces taken from the CAFE database. Participants, all Italians, were recruited through e-mails and social networks; they joined the study after reading and agreed to an informed consent formulated according to the Italian and European laws about privacy and data protection. The research was authorized by the ethical committee of the Department of Psychology at the Università degli Studi della Campania "Luigi Vanvitelli" with the protocol number 25/2017.

B. Stimuli

The emotional decoding task required participants to decode images of female and male children, belonging to different ethnicity (European, African American, Latino American, and Asian) expressing anger, disgust, fear, happiness, sadness, surprise, and neutrality. Pictures were taken from the Child Affective Facial Expression Set (CAFÉ) [19]. The database consists of a collection of pictures depicting children of 2- to 8- year-old, interpreting emotional facial emotional expressions of sadness, happiness, surprise, anger, disgust, and fear and neutrality. The database includes female and male actors of different ethnicity (African American, Asian, European/ European American, Latino, and South Asian). The current experiment exploits fifty-six faces of European, African American, Latino American, and Asian children displaying the seven facial expressions of anger, disgust, fear, happiness, sadness, surprise, and neutrality (for each emotional category were selected 8 pictures, a male and a female child for each ethnicity). Unfortunately, since the images in the CAFE dataset are copyright protected cannot be published. If interested in visioning the stimuli is possible to require them at: https://nyu.databrary.org/volume/30.

C. Tools and Procedures

The study was developed using Lab.js, an online study builder, successively exported on JATOS, a tool allowing to generate the links that have been given to participants. Each participant was provided with a link to be opened from a laptop. Once opened the link, participants gave their consent to a personal data processing form and after this participants' demographic data were collected. The study consisted in a trial session (composed by six static images) and by an experimental session (composed by fifty-six static images), both characterized by the presentation of randomized stimuli. For each picture, participants were required to select an emotional label choosing among these options: disgust, anger, sadness, fear, happiness, surprise, neutrality. If, according to the participant, the emotion was not described by none of the proposed category they were given the possibility to select the "other emotion" option of response (this option was considered in order to try to influence participants' answer as little as possible, allowing them further freedom while selecting the answer).

III. Data Analysis and Results

A. Data Description

The dependent variable measured in our study is emotion recognition accuracy; we investigated how it is affected by variables (which represent the independent variables of the study) related to the participants (as their gender and genitoriality) and by variables related to the stimulus (as the gender and the ethnicity); study's independent variables are summarized in Table 1. For each emotional category (disgust, anger, sadness, fear, happiness, surprise, neutrality) 8 stimuli were shown (one male and one female child for each ethnicity). When participants correctly decoded the emotion portrayed by a stimulus the answer was coded with the scoring "1", while when the emotion was not correctly recognized the scoring was equal to "0", table 2 summarize this information. Means of recognition accuracy vary from 0 to 1 concerning the statistical analysis performed singularly for each emotional category (section C), while vary from 0 to 8, for the analysis performed on emotional category total decoding scores (section B). In the following sections will be shown the statistical procedure used to the test the effects of the previously mentioned variables on emotion recognition accuracy, more specifically we used Repeated measures ANOVA's since it allowed us to test both the effects of between subjects' variables (such as participants' gender and genitoriality) and within subjects' variables (such as stimuli's gender and ethnicity) on emotion recognition accuracy.

TABLE I
STUDY'S INDEPENDENT VARIABLES

Participants' Gender	*Participants' Genitoriality*	*Stimuli's Gender*	*Stimuli's Ethnicity*
Twenty-four males Thirty-six females	Thirty parents Thirty child-free	Female and male children static faces	Static faces of children belonging to different ethnicity (European, African American, Latino American, Asian)

TABLE II
STUDY'S DEPENDENT VARIABLE (Recognition Accuracy)

Typology of stimulus for each emotional category	*Recognition Accuracy Scores*
Male European	1=stimulus correctly decoded 0=stimulus wrong decoded
Male African American	
Male Latino American	
Male Asian	
Female European	
Female African American	
Female Latino American	
Female Asian	

B. Emotional total scores

A first elaboration of the data was performed with the aim to assess participants' ability to correctly decode the proposed emotional categories (i.e., anger, disgust, fear, happiness, sadness, surprise, and neutrality.) independently from the age and the ethnicity of the faces. Repeated measures ANOVA were performed on the collected data, considering participants' gender and group (parents and childless) as between subjects' variables, and total decoding scores of the proposed emotional category as within subjects' variables. The significance level was set at $\alpha < .05$ and differences among means were assessed through Bonferroni's post hoc tests.

Significant differences [F (6, 336) = 57.368, p<<.01] emerged concerning emotions recognition scores. Bonferroni post-hoc tests revealed that each emotional category significantly differed from each other: Happiness (mean=7.618), Surprise (mean=7.511), Anger (mean=7.013), Disgust (mean=6.662), Neutrality (mean=6.500), Sadness (mean=5.253), Fear (mean=4.099), p<.01; between anger and surprise the difference was slightly lower (p=.038).

The only exceptions were represented by Disgust, which did not significantly differ from Anger (p=1.000) and Neutrality (p=1.000), by Anger which did not significantly differ from Neutrality (p=.980) and by Happiness which did not significantly differ from Surprise (p=1.000). Figure 1 shows these results.

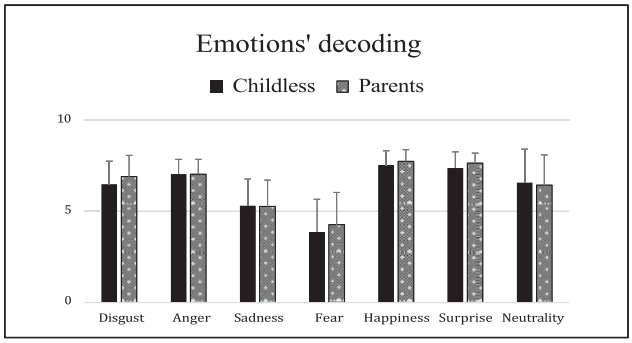


Fig. 1. Recognition scores of childless participants and parents for each emotional category. Y- axis means vary between 0 and 8 and represent for each emotional category total decoding scores.

C. Effects of faces' gender and ethnicity

To test the effect of some variables as the gender and the ethnicity of the showed faces on emotion decoding accuracy, ANOVA repeated measures analyses were carried out for each emotional category (disgust, anger, fear, sadness, happiness, surprise, and neutrality) considering participants' group (parents and childless) as between subjects' factors, and gender and ethnicity of stimuli (European, African American, Latino American, and Asian) as within factors. The significance level was set at $\alpha < .05$ and differences among means were assessed through Bonferroni's post hoc tests.

Disgust

Significant effects of the gender of stimuli were observed [F (1,56) = 12.444, p=.001]. Bonferroni post hoc tests revealed that this was due to female facial expressions (mean=.894) which were better recognized compared to male facial expressions (mean=.771, p=.001).

Significant effects of the ethnicity of stimuli were observed [F (3, 168) = 9.816, p<<.01]. Bonferroni post hoc tests revealed that this was due to African American facial expressions (mean=.979) which were better recognized compared to European (mean=.756, p<<.01), Latino American (mean=.784, p<<.01) and Asian (mean=.811, p<<.01) facial expressions.

A significant interaction emerged [F (3,168) = 5.783, p=.001] between gender and ethnicity of stimuli. Bonferroni's post hoc tests were performed for each single factor (gender and ethnicity of stimuli). These tests revealed that:

a) Concerning gender of stimuli: Female Latino American faces were better decoded (mean=.945) compared to male Latino American faces (mean=.624, p<<.01).

b) Concerning ethnicity of stimuli: as regard as male faces, African American faces were better decoded (mean=.972) compared to European (mean=.693, p<<.01), Latino American (mean=.624, p<<.01) and Asian (mean=.796, p=.001) facial expressions. As regard as female faces, African American faces were better decoded (mean=.987) compared to European (mean=.819, p=.010) and Asian (mean=.826, p=.011) facial expressions. Figure 2 shows these results.

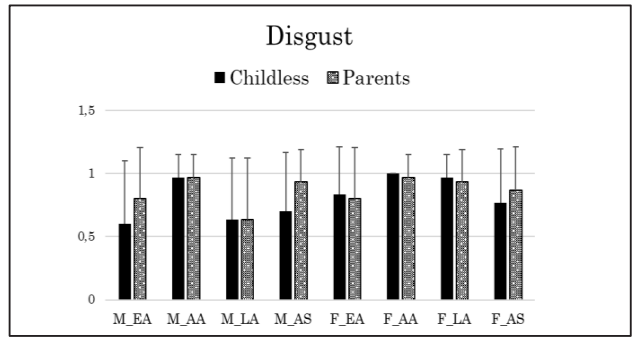


Fig. 2. Recognition scores of childless participants and parents for disgust. Means are showed for each stimulus, the first letter indicates the gender of the face (M=male, F=female), letters after the underscore refers to faces' ethnicity (EA=european, AA=african american, LA=latino american, AS=asian).

Anger

Anger Significant effects of the ethnicity of stimuli were observed [F (3, 168) = 30.405, p<<.01]. Bonferroni post hoc tests revealed that this was due to Asian facial expressions (mean=.667) which were worse recognized compared to European (mean=.971, p<<.01), Latino American (mean=.894, p<<.01) and African American (mean=.975, p<<.01) facial expressions. Figure 3 summarize these results.

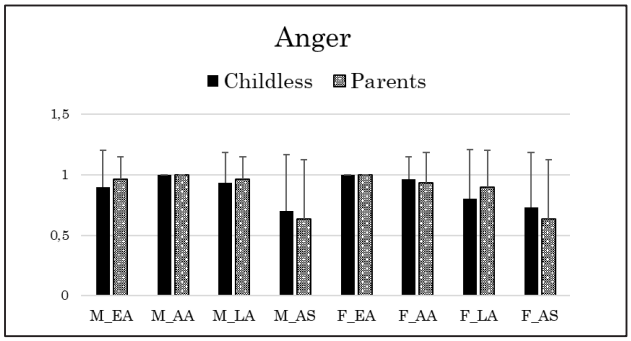


Fig. 3. Recognition scores of childless participants and parents for anger. Means are showed for each stimulus, the first letter indicates the gender of the face (M=male, F=female), letters after the underscore refers to faces' ethnicity (EA=european, AA=african american, LA=latino american, AS=asian).

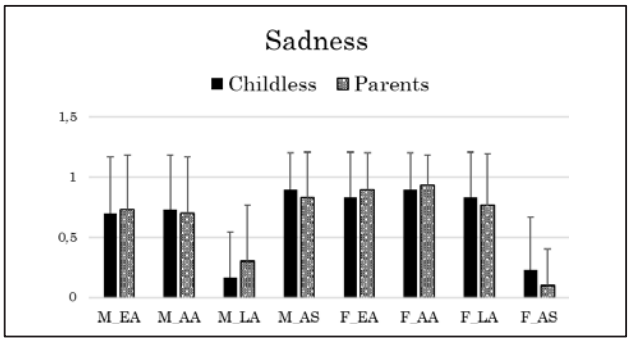


Fig. 4. Recognition scores of childless participants and parents for sadness. Means are showed for each stimulus, the first letter indicates the gender of the face (M=male, F=female), letters after the underscore refers to faces' ethnicity (EA=european, AA=african american, LA=latino american, AS=asian).

Sadness

Significant effects of the ethnicity of stimuli were observed [F (3, 168) = 21.017, p<<.01]. Bonferroni post hoc tests revealed that this was due to Latino American (mean=.520) and Asian facial expressions (mean=.514) which were worse decoded compared to European (mean=.783, p<<.01) and African American (mean=.809, p<<.01) faces.

A significant interaction emerged [F (3,168) = 63.815, p=.001] between gender and ethnicity of stimuli. Bonferroni's post hoc tests were performed for each single factor (gender and ethnicity of stimuli). These tests revealed that:

a) Concerning gender of stimuli: Female European faces were better decoded (mean=.864) compared to male European faces (mean=.702, p=.021); female African American faces were better decoded (mean=.915) compared to male African American faces (mean=.703, p=.003); female Latino American faces were better decoded (mean=.802) compared to male Latino American faces (mean=.239, p<<.01); male Asian faces were better decoded (mean=.857) compared to female Asian faces (mean=.170, p<<.01).

b) Concerning ethnicity of stimuli: as regard as male faces, Latino American faces were worse decoded (mean=.239) compared to European (mean=.702, p<<.01), African American (mean=.703, p<<.01) and Asian (mean=.857, p<<.01) facial expressions. As regard as female faces, Asian faces were worse decoded (mean=.170) compared to European (mean=.864, p=.010), African American (mean=.915, p=.011) and Latino American (mean=.802, p<<.01) facial expressions. Figure 4 summarize these results.

Fear

Significant effects of the gender of stimuli were observed [F (1, 56) = 57.083, p<<.01]. Bonferroni post hoc tests revealed that this was due to female facial expressions (mean=.647) which were better recognized compared to male facial expressions (mean=.378, p<<.01).

Significant effects of the ethnicity of stimuli were observed [F (3, 168) = 14.963, p<<.01]. Bonferroni post hoc tests revealed that this was due to Latino American facial expressions (mean=.288) which were worse recognized compared to European (mean=.631, p<<.01), African American (mean=.587, p<<.01) and Asian (mean=.543, p<<.01) facial expressions.

A significant interaction emerged [F (3,168) = 32.087, p<<.01] between gender and ethnicity of stimuli. Bonferroni's post hoc tests were performed for each single factor (gender and ethnicity of stimuli). These tests revealed that:

a) Concerning gender of stimuli: Female European faces were better decoded (mean=1.000) compared to male European faces (mean=.262, p<<.01); female African American faces were better decoded (mean=.805) compared to male African American faces (mean=.370, p<<.01); male Latino American faces were better decoded (mean=.369) compared to female Latino American faces (mean=.207, p=.028).

b) Concerning ethnicity of stimuli: as regard as male faces, Asian were better decoded (mean=.510) compared to European (mean=.262, p=.020). As regard as female faces, Latino American faces were worse decoded (mean=.207) compared to European (mean=1.000, p<<.01), African American (mean=.805, p<<.01) and Asian (mean=.576, p<<.01) facial expressions. Figure 5 summarize these results.

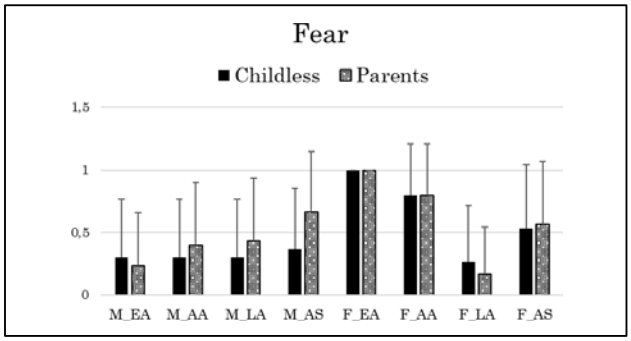


Fig. 5. Recognition scores of childless participants and parents for fear. Means are showed for each stimulus, the first letter indicates the gender of the face (M=male, F=female), letters after the underscore refers to faces' ethnicity (EA=european, AA=african american, LA=latino american, AS=asian).

Happiness

Significant effects of the gender of stimuli were observed [F (1, 56) = 5.323, p=.025]. Bonferroni post hoc tests revealed that this was due to male facial expressions (mean=.973) which were better recognized compared to female facial expressions (mean=.932, p=.025). Figure 6 show these results.

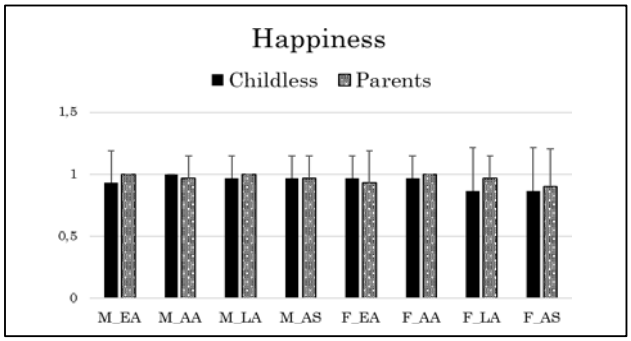


Fig. 6. Recognition scores of childless participants and parents for happiness. Means are showed for each stimulus, the first letter indicates the gender of the face (M=male, F=female), letters after the underscore refers to faces' ethnicity (EA=european, AA=african american, LA=latino american, AS=asian).

Surprise

Significant effects of the gender of stimuli were observed [F (1, 56) = 6.172, p=.016]. Bonferroni post hoc tests revealed that this was due to male facial expressions (mean=.964) which were better recognized compared to female facial expressions (mean=.913, p=.016).

A significant interaction emerged [F (3,168) = 8.379, p<<.01] between gender and ethnicity of stimuli. Bonferroni's post hoc tests were performed for each single factor (gender and ethnicity of stimuli). These tests revealed that:

a) Concerning gender of stimuli: male European faces were better decoded (mean=.985) compared to male European faces (mean=.860, p=.020); male Latino American faces were better decoded (mean=1.000) compared to female Latino American faces (mean=.828, p=.001); female Asian faces were better decoded (mean=.985) compared to male ones (mean=.872, p=.010).

b) Concerning ethnicity of stimuli: as regard as male faces, African American (mean=1.000) and Latino American (mean=1.000) facial expressions were better decoded compared to European (mean=.985, p=.039) and Asian facial expressions (mean=.872, p=.039). As regard as female faces, Latino American faces were worse decoded (mean=.828) compared to African American (mean=.981, p=.016) and Asian (mean=.985, p=.032) facial expressions. Figure 7 show these results.

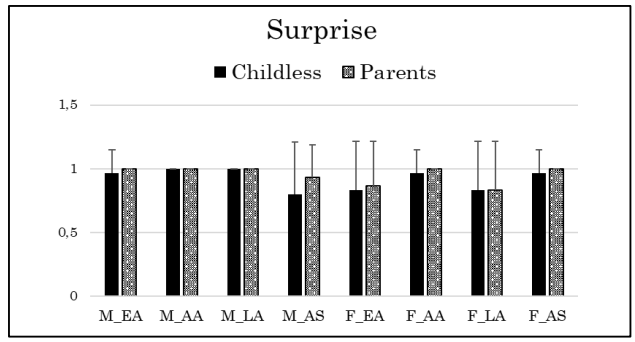


Fig. 7. Recognition scores of childless participants and parents for surprise. Means are showed for each stimulus, the first letter indicates the gender of the face (M=male, F=female), letters after the underscore refers to faces' ethnicity (EA=european, AA=african american, LA=latino american, AS=asian).

Neutrality

Significant effects of the ethnicity of stimuli were observed [F (3, 168) = 5.656, p=.001]. Bonferroni post hoc tests revealed that this was due to Latino American (mean=.911) which were better decoded compared to African American (mean=.777, p=.035) and Asian (mean=.726, p=.002) faces.

A significant interaction emerged [F (3,168) = 13.326, p=.001] between gender and ethnicity of stimuli. Bonferroni's post hoc tests were performed for each single factor (gender and ethnicity of stimuli). These tests revealed that:

a) Concerning gender of stimuli: Female European faces were better decoded (mean=.951) compared to male European faces (mean=.721, p<<.01); male Asian faces were better decoded (mean=.865) compared to female Asian faces (mean=.587, p<<.01).

b) Concerning ethnicity of stimuli: as regard as male faces, Latino American faces were better decoded (mean=.951) compared to European (mean=.721, p=.005). As regard as female faces, Asian faces were worse decoded (mean=.587) compared to European (mean=.951, p<<.01), African American (mean=.783, p=.034) and Latino American (mean=.871, p=.001) facial expressions. Figure 8 show these results.

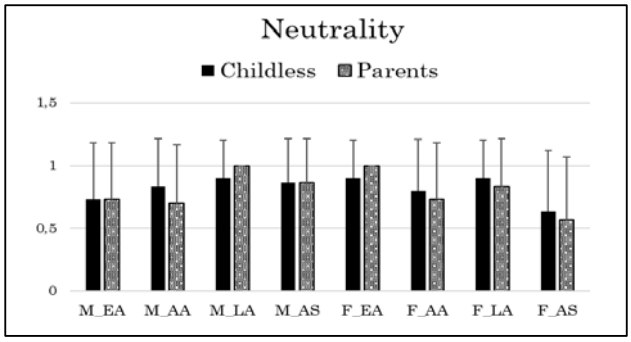


Fig. 8. Recognition scores of childless participants and parents for neutrality. Means are showed for each stimulus, the first letter indicates the gender of the face (M=male, F=female), letters after the underscore refers to faces' ethnicity (EA=european, AA=african american, LA=latino american, AS=asian

TABLE III
CHILDLESS PARTICIPANTS' AND PARENTS DECODING ACCURACY (IN %) OF EMOTIONAL FACES

	Decoding accuracy of children faces in %						
	Disgust	*Anger*	*Sadness*	*Fear*	*Happiness*	*Surprise*	*Neutral*
Childless	80.8	87.9	66.3	48.3	94.2	92.1	82.1
Parents	86.3	87.9	65.8	53.3	96.7	95.4	80.4

TABLE IV
CONFUSION MATRICES OF CHILDLESS PARTICIPANTS' DECODING ACCURACY (IN %) FOR EACH EMOTIONAL CATEGORY

Childless %								
	Disgust	*Anger*	*Sadness*	*Fear*	*Happiness*	*Surprise*	*Neutral*	*Other emotion*
Disgust	**80.8**	9.6	5.0	0.8	0.0	0.0	0.0	3.8
Anger	4.2	**87.9**	3.3	1.3	0.0	0.0	0.0	3.3
Sadness	13.8	0.0	**66.3**	4.6	0.0	0.4	4.6	10.4
Fear	5.4	0.8	1.3	**48.3**	0.4	33.3	2.1	8.3
Happiness	0.4	0.0	2.1	0.0	**94.2**	0.8	1.7	0.8
Surprise	0.0	0.0	0.0	5.0	2.5	**92.1**	0.0	0.4
Neutral	0.4	4.2	5.0	4.2	0.0	0.4	**82.1**	3.8
Disgust	80.8	9.6	5.0	0.8	0.0	0.0	0.0	3.8

TABLE V
CONFUSION MATRICES OF PARENTS' DECODING ACCURACY (IN %) FOR EACH EMOTIONAL CATEGORY

Parents %								
	Disgust	*Anger*	*Sadness*	*Fear*	*Happiness*	*Surprise*	*Neutral*	*Other emotion*
Disgust	**86.3**	8.8	3.8	0.0	0.0	0.0	0.0	1.3
Anger	5.4	**87.9**	2.9	0.8	0.0	0.0	0.0	2.9
Sadness	16.7	0.8	**65.8**	3.8	1.3	2.1	3.3	6.3
Fear	1.7	1.3	0.8	**53.3**	0.4	35.0	2.1	5.4
Happiness	0.4	0.0	0.0	0.4	**96.7**	0.8	0.8	0.8
Surprise	0.0	0.0	0.0	2.5	2.1	**95.4**	0.0	0.0
Neutral	0.8	3.8	7.9	2.1	0.0	0.8	**80.4**	4.2
Disgust	86.3	8.8	3.8	0.0	0.0	0.0	0.0	1.3

IV. DISCUSSION

The presented work provides an investigation aimed at exploring whether and how variables, such as participants' gender and parenting, as well as the gender and the ethnicity of the stimulus administered, in this case children static faces, affect the process of decoding emotional expressions. Testing the effects of these factors on people's ability to decode emotions, could be helpful in order to increase knowledge concerning this fundamental human cognitive process. Participants, split in childless and parents, were administered an emotion recognition task depicting children's facial expressions belonging to different ethnicity (European, African American, Latino American, and Asian) and required to select an emotional label to each picture choosing among anger, disgust, fear, happiness, sadness, surprise, and neutrality. We observed that the factors which mostly influenced results were the gender and the ethnicity of the showed faces, even if these effects vary according to the emotional category analyzed.

For instance, as regards as faces' gender, disgust and fear were more accurately decoded when conveyed by female children, while happiness and surprise were better decoded on male children faces. In literature the impact of the gender of a face conveying an emotion on facial expressions' accuracy recognition has been widely investigated. A well-known theory concerns the "Own Gender Bias" according to which people should easily decode faces of their same gender compared to faces of the other gender [12][13]. Nevertheless, our investigation does not confirm this bias but rather highlighted that variables as for instance the gender of a face, could not have an absolute effect on emotion recognition abilities, rather seems to be mediated by the emotional category considered.

Ethnicity is a fundamental factor in the field of emotion recognition, even considering the concept of "Racialized Emotion Recognition Accuracy" suggesting that humans are ethically prejudiced when decoding emotions, in particular when attributing anger [16][17][18] and that this is true not only while decoding adults' facial expressions but children' faces as well [20]. As regards as our study once again the effect of this factor depends on the emotional category considered. When decoding disgust, African American faces were more accurately decoded; when recognizing anger Asian facial expressions were worse decoded while when decoding sadness Asian and Latino American faces were less accurately recognized. Concerning fear, once again Latino American children were worse decoded, while on the contrary when decoding neutrality participants better decoded Latino American faces with respect to the other ethnicities. Still, when focusing on the ethnicity of a face, scientific studies encourage the existence of a facilitation effect, known as Own-Ethnicity Bias [21], according to which people would better process faces that belong to their own ethnicity. But once again our results do not confirm this hypothesis, as we should have observed, considered that our participants were

all European, that facial expressions of European children would have been systematically better recognized compared to those of other ethnicities, but this was not the case. Indeed, for many emotional categories African American faces have been better recognized, confirming once again that the influence of variables such as the ethnicity of a face have on facial expressions processing is not a direct effect, rather this could interact with other variables, like the features of the face itself.

Even tough statistical analyses do not highlight significant differences between childless participants and parents, examining percentages of decoding accuracy (table 3) we observed that Sadness and Neutrality were more accurately decoded by childless participants, while Disgust, Fear, Happiness, and Surprise were more accurately decoded by parents. These results are very interesting as they partially confirm one of the initial questions that inspired the study, namely the desire to investigate whether in some way the fact that a person is (or has been) exposed to children's facial expressions on a daily basis could facilitate him/her while decoding emotional expressions conveyed by children compared to a person who does not have daily intercourse with children. Our results show that for most of the emotional categories investigated this is true, as parents showed higher recognition accuracy rates compered to childless participants. The only exceptions were represented by Sadness and Neutrality, which instead were more accurately recognized by childless subjects. Interesting insights were also provided by confusion matrices showing the percentage of participants' decoding accuracy for each emotional category for both the groups of childless participants and parents (tables 4 and 5), which showed that disgust, anger, happiness, surprise, and neutrality were correctly classified by both groups, which showed a percentage of decoding accuracy higher than 80%. Some misclassifications were observed, in both groups, concerning sadness, mostly confused with disgust, or identified as other emotion, and fear, mostly confused with surprise, as expected since fear and surprise are often blended in facial expressions [22]. Moreover, was observed that the emotional categories better decoded were Disgust, Anger, Happiness, Neutrality, and Surprise, while Sadness and Fear were the emotional categories worse decoded by both groups of participants.

V. Conclusions

5), which showed that disgust, anger, happiness, surprise, and neutrality were correctly classified by both groups, which showed a percentage of decoding accuracy higher than 80%. Some misclassifications were observed, in both groups, concerning sadness, mostly confused with disgust, or identified as other emotion, and fear, mostly confused with surprise, as expected since fear and surprise are often blended in facial expressions [22]. Moreover, was observed that the emotional categories better decoded were Disgust, Anger, Happiness, Neutrality, and Surprise, while Sadness and Fear were the emotional categories worse decoded by both groups of participants.

Acknowledgement

The research leading to these results received funding from the EU-H2020 program grant No. 823907 (MENHIR), from the project SALICE that received funding from Università della Campania "Luigi Vanvitelli" inside the program Giovani Ricercatori (DR 509/2022), funded with DR 834/2022, from the EU NextGenerationE, PNRR Mission 4 Component 2 Investment 1.1 – D.D 1409 del 14-09-2022 PRIN 2022 – Project code "P20222MYKE" - CUP: B53D23025980001 (IRRESPECTIVE) and scolarship DM 118/2023 PNRR (M4C1 – Inv. 4.1 "Ricerca PNRR") funded by Università Studi della Campania "Luigi Vanvitelli".

References

[1] Orgeta, V., & Phillips, L. H. (2007). Effects of age and emotional intensity on the recognition of facial emotion. *Experimental aging research*, 34(1), 63–79.

[2] Richter, D., Dietzel, C., & Kunzmann, U. (2011). Age differences in emotion recognition: The task matters. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 66(1), 48–55.

[3] Kessels, R. P., Montagne, B., Hendriks, A. W., Perrett, D. I., & de Haan, E. H. (2014). Assessment of perception of morphed facial expressions using the Emotion Recognition Task: Normative data from healthy participants aged 8–75. *Journal of neuropsychology*, 8(1), 75–93.

[4] Rigon, A., Turkstra, L., Mutlu, B., & Duff, M. (2016). The female advantage: sex as a possible protective factor against emotion recognition impairment following traumatic brain injury. *Cognitive, Affective, & Behavioral Neuroscience*, 16(5), 866–875.

[5] Weisenbach, S. L., Rapport, L. J., Briceno, E. M., Haase, B. D., Vederman, A. C., Bieliauskas, L. A., ... & Langenecker, S. A. (2014). Reduced emotion processing efficiency in healthy males relative to females. *Social cognitive and affective neuroscience*, 9(3), 316–325.

[6] Lambrecht, L., Kreifelts, B., & Wildgruber, D. (2014). Gender differences in emotion recognition: Impact of sensory modality and emotional category. *Cognition & emotion*, 28(3), 452–469.

[7] Amorese, T., Cuciniello, M., Vinciarelli, A., Cordasco, G., & Esposito, A. (2021). Synthetic vs Human Emotional Faces: What Changes in Humans' Decoding Accuracy. *IEEE Transactions on Human-Machine Systems*, 52(3), 390–399.

[8] Hills, P. J., & Lewis, M. B. (2011). Rapid communication: The own-age face recognition bias in children and adults. *Quarterly Journal of Experimental Psychology*, 64(1), 17–23.

[9] Esposito, A., Esposito, A. M., Cordasco, G., Maldonato, M., Vogel, C., & Bourbakis, N. (2018, August). Emotional faces of children and adults: What changes in their perception. In *2018 9th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)* (pp. 000 099–000 104). IEEE.

[10] Man, T. W., & Hills, P. J. (2016). Eye-tracking the own-gender bias in face recognition: Other-gender faces are viewed differently to own-gender faces. *Visual Cognition*, 24(9-10), 447–458.

[11] Hoffmann, H., Kessler, H., Eppel, T., Rukavina, S., & Traue, H. C. (2010). Expression intensity, gender, and facial emotion recognition: Women recognize only subtle facial emotions better than men. *Acta psychologica*, 135(3), 278–283.

[12] Wolff, N., Kemter, K., Schweinberger, S. R., & Wiese, H. (2014). What drives social in-group biases in face recognition memory? ERP evidence from the own-gender bias. *Social Cognitive and Affective Neuroscience*, 9(5), 580–590.

[13] Man, T. W., & Hills, P. J. (2016). Eye-tracking the own-gender bias in face recognition: Other-gender faces are viewed differently to own-gender faces. *Visual Cognition*, 24(9-10), 447–458.

[14] Meissner, C. A., & Brigham, J. C. (2001). Thirty years of investigating the own-race bias in memory for faces: A meta-analytic review. *Psychology, Public Policy, and Law*, 7(1), 3–35. DOI: 10.1037/1076-8971.7.1.3

[15] Wright, D. B., Boyd, C. E., and Tredoux, C. G. (2003). Inter-racial contact and the own-race bias for face recognition in South Africa and England. *Appl*. *Cognit*.*Psychol*. 17, 365–373. DOI: 10.1002/acp.898

[16] Elfenbein, H. A., & Ambady, N. (2002). On the universality and cultural specificity of emotion recognition: a meta-analysis. *Psychological bulletin*, 128(2), 203.

[17] Halberstadt, A. G., Castro, V. L., Chu, Q., Lozada, F. T., & Sims, C. M. (2018). Preservice teachers' racialized emotion recognition, anger bias, and hostility attributions. *Contemporary Educational Psychology*, 54, 125–138.

[18] Hugenberg, K., & Bodenhausen, G. V. (2003). Facing prejudice: Implicit prejudice and the perception of facial threat. *Psychological Science*, 14(6), 640–643.

[19] LoBue, V., & Thrasher, C. (2015). The Child Affective Facial Expression (CAFE) set: Validity and reliability from untrained adults. *Frontiers in psychology*, 5, 1532.

[20] Halberstadt, A. G., Cooke, A. N., Garner, P. W., Hughes, S. A., Oertwig, D., & Neupert, S. D. (2022). Racialized emotion recognition accuracy and anger bias of children's faces. *Emotion*, 22(3), 403.

[21] Gross, T. F. (2009). Own-ethnicity bias in the recognition of Black, East Asian, Hispanic, and White faces. *Basic and Applied Social Psychology*, 31(2), 128–135.

[22] Ekman, P. (1976). Pictures of facial affect. *Consulting Psychologists Press*.

Terry Amorese

Anna Esposito

Marialucia Cuciniello, **Claudia Greco, Gennaro Cordasco**

Special Issue of the Infocommunication Journal

The Effects of Immersion Level, Human Characteristics, and a Virtual Scale on Exocentric Distance Perception

Tibor Guzsvinecz, Judit Szűcs, and Erika Perge

Abstract—**Understanding spatial perception is crucial in virtual environments since it influences navigation abilities. To better understand how human characteristics combined with immersion levels influence exocentric distance estimation, this study was conducted. We have implemented a virtual environment for the desktop display and the Gear VR head-mounted display, in which we assessed these skills of 229 university students. 157 used the former, while 72 used the latter display device. The results show that human characteristics combined with the two display devices as well as a virtual scale have significant effects on exocentric distance estimation. The findings can help the development of more accessible virtual environments in the future.**

Index Terms—**desktop display, exocentric distance estimation, Gear VR, head-mounted display, human–computer interaction, immersion, virtual environment**

I. Introduction

EXOCENTRIC distance is defined as the distance between external objects or points from the observer's perspective. Accurate distance perception in the real world is essential for various aspects of daily life, including navigation, spatial awareness, and activities (such as driving and sports). Distance estimation plays a critical role in avoiding obstacles, decision-making, and interacting with our surroundings [1–3].

In virtual reality (VR), the accurate estimation of distances is crucial for creating immersive and realistic experiences. As users navigate virtual environments (VEs), their cognitive ability to estimate distances directly impacts their interactions and decision-making during the process. The whole process can be addressed in the fields of Cognitive Aspects of Virtual Reality (cVR) and Cognitive InfoCommunications (CogInfoCom) since they primarily focus on human cognition. They aim to showcase the latest advancements in information and communication technologies (ICT) that facilitate the interaction between humans and machines [4–9]. Furthermore, it is worth mentioning that CogInfoCom and cVR are closely related [10].

However, it is important to investigate human-computer interaction regarding distance perception due to the fact that in VR applications like training simulations [11, 12], education [13, 14], and gaming [15, 16], users must rely on their distance estimation skills for navigation. According to the literature, users tend to underestimate distances in VR applications [17, 18]. While this underestimation can be decreased [19], it is influenced by several factors. The first factor is the composition of VEs, since they can be constructed differently. Consequently, distance perception can be affected by visual cues such as textures, graphics, and even avatars [20–24]. The other affecting factor is the technology used, such as display devices (especially the level of immersion), as well as the effect of binocular disparity [25–28]. The third factor is the distance itself: studies show that distances up to approximately 1 m are usually overestimated, but accurate estimates can occur up to 55 cm [29]. Lastly, the fourth factor is the 'human one' (i.e. demographic data of the users). Studies show that gender and age can significantly affect distance estimation [30–32]. We also explored the effects of human characteristics such as gender, height, dominant hand, gaming hours per week, previous VR experience, wearing glasses, and field of study in another paper. Our results showed that the latter two factors did not have significant effects on the accuracy of distance estimates or estimation time [33].

The influence of human factors has a large importance because VR redefines human-computer interfaces, and humans play a crucial role in such systems [34]. According to the literature, cognition plays an important role in interacting with virtual spaces [10], and VEs can even enhance the cognitive skills of humans [35]. Studies also emphasize the importance of focusing on humans during the development of VEs [6, 7]. Thus, it is crucial to understand these factors to enhance VR experiences while creating accessible experiences for a diverse range of users. In this study, the aim is to investigate how certain combinations of factors affect exocentric distance perception. Therefore, our research question is the following: *Do gender, height, dominant hand, gaming hours per week, previous VR experience, wearing glasses, and current studies combined with immersion levels, and a virtual scale influence exocentric distance estimates?*

Tibor Guzsvinecz is with the Department of Information Technology and its Applications, Faculty of Information Technology, University of Pannonia, Zalaegerszeg, Hungary (e-mail: guzsvinecz.tibor@zek.uni-pannon.hu). He is the corresponding author.

Judit Szűcs is with the Department of Information Technology and its Applications, Faculty of Information Technology, University of Pannonia, Zalaegerszeg, Hungary (e-mail: szucs.judit@zek.uni-pannon.hu).

Erika Perge is with the Department of Basic Technical Studies, Faculty of Engineering, University of Debrecen, Debrecen, Hungary (e-mail: perge@eng.unideb.hu)

DOI: 10.36244/ICJ.2025.6.4

The paper has the following structure. Section II presents the materials and methods, including details of the VE, data collection, and analysis. The results are presented in Section III. Afterward, discussion is shown in Section IV, while conclusions are made in Section V.

II. Materials and Methods

This section is split into three subsections. In Subsection A, the developed VE is presented. Subsection B contains the data collection process. Lastly, the data analysis is shown in Subsection C.

A. Details of the virtual environment

The mentioned VE was developed in Unity game development engine (version 2018.4.36f1). Two versions were created: an immersive version for the Gear VR, and a non-immersive version for the desktop display (LG 20M37A (19.5")). Naturally, the Gear VR uses Android platform, whereas the latter one uses Windows operating system. The Windows one is also referred to as the 'PC version' in this study. Also, the smartphone used in the Gear VR was a Samsung Galaxy Edge S6+. The two versions were identical, except for the immersion level and the controls. The PC version is controlled with a keyboard and a mouse, whereas the Gear VR version can be controlled with the rotation of the user's head and by tapping its touchpad on its right side. The participants can only look around in the virtual space. It was not possible to walk in it due to technical constraints.

After starting the application, the participants are taken into the main menu. In it, they have to enter some information about themselves. Upon completion, they had to press the start button. Afterward, they are placed into the middle of the room at their actual (entered) height. The room was 12 m wide on each side, meaning that each wall was 6 m away from the participants. The room can be observed in Figs. 1 and 2.

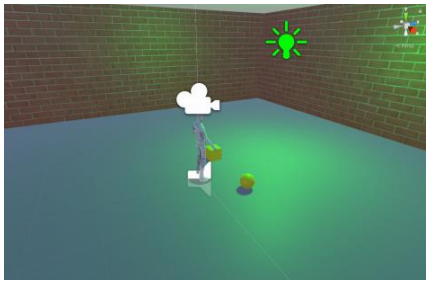


Fig. 1. The virtual environment without a scale (seen from the Unity editor).

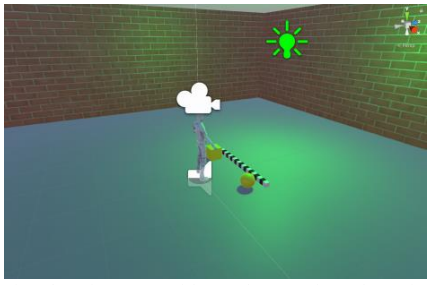


Fig. 2. The virtual environment with a scale (seen from the Unity editor).

As seen in Figs. 1 and 2, two objects were in front of the participants' avatar. Both objects had three types that were randomized. They could either be a cylinder, cube or a sphere. Their exocentric distances were also randomized between 60-150 cm at 10 cm intervals in each round. Every distance had to be encountered two times by the participant. Firstly, all without the scale, and afterward, all with the scale, but in both cases in randomized order. Therefore, the whole measurement process had 20 rounds. The scale had 19 cubes on the ground. The size of each cube on the scale was $10\ \text{cm} \times 10\ \text{cm} \times 10\ \text{cm}$.

B. The data collection process

The University of Pannonia and the University of Debrecen were the sites of the data collection process which occurred in the fall of 2022. The Gear VR version was used at the former university, while the PC version was used at the latter. The skills of 72 students were measured with the Gear VR ($M_{age} = 22.51, SD_{age} = 6.63$). These participants were IT students. With the desktop display, the distance perception ability of 157 students was measured ($M_{age} = 19.80$, $SD_{age} = 2.09$). Out of these, 81 were civil engineering ($M_{age} = 19.72, SD_{age} = 2.32$), 27 were mechanical engineering ($M_{age} = 20.18, SD_{age} = 2.45$) and 49 were vehicle engineering students ($M_{age} = 19.71, SD_{age} = 1.34$). All participants joined the measurements of their own volition and gave informed consent for the process. No names were gathered. However, we asked the participants to provide their following non-identifying data: gender; age; height; dominant hand; whether they wore glasses; their field of study; how many hours of video games they play per week; and whether they had any previous VR experience. This information had to be entered in the main menu of the application.

Before the measurements started, information was given about them. The participants were briefed on the following. They were instructed how to look around in the virtual space, and how to estimate distances. We also told them the dimensions of the room and the scale. On PC, participants had to enter the distances using the keyboard. It was not even necessary to click on the input box. With the Gear VR, they had to say the estimated distances to the researcher next to them, who wrote it into a file. After either was completed, the participants had to look up at the ceiling and press enter on the keyboard or the touchpad on the Gear VR. After doing so, the next round started at another distance. The first 10 rounds were without the scale, while the scale appeared for the second 10 rounds. If the participants completed all 20 rounds, the tests were over. Again, all the distances arose in both types, but in randomized order.

After each round, the application wrote the data into a file with CSV type. The data looked like the following: every line was a round, and it contained all factors that were present during the measurement. This meant the human characteristics, actual and estimated distances, estimation times, et cetera.

C. Analysis of data

When the data collection process was completed, the mentioned CSV file was imported into the statistical program

package R. However, before the analyses started, several groups were created based on heights and video game playtime per week. 11 groups were created of the former, whereas six were created of the latter one. Regarding height, the shortest person was 150 cm, whereas the tallest was 202 cm. Therefore, the 11 groups were created at five-centimeter intervals (150-154 cm, 155-159 cm, and so on). Regarding video game playtime per week, the following groups were made on an empirical basis: 0 hours; 1-2 hours; 3-4 hours; 5-10 hours; 11-19 hours; and 20 or more hours.

For the first step of the investigation, the estimates were deemed either accurate or inaccurate. An estimate was considered accurate if it ranged within ±10% of the actual distance. This classification yielded 1274 accurate estimates and 3306 inaccurate ones. For the investigation, an alpha value of 0.05 was chosen. The Shapiro-Wilk test was used to examine the distributions of the data. Due to the distributions, the Wilcoxon rank sum test was used when comparing the general results. To see the effects of the various objects in the VE, the Kruskal-Wallis rank sum test was used. Logistic regression analysis method was used to understand the effects of the influence of human characteristics and immersion levels with or without the scale on the probability of accurate estimates. The log-odds returned by the logistic regression analysis can be converted to percentages using Equation (1).

$$\% = (e^{LO} - 1) \cdot 100 \quad (1)$$

, where LO stands for the log-odds. The basis (intercept) variables were chosen by R automatically. Usually, the first one is chosen in the alphabet. The strengths of the effects are presented in the form of 95% confidence intervals (CIs). The basis variables are omitted from the figures.

III. Results

In this section, the results are shown within several subsections. Each details the results of a pair of factors. Before continuing to the analysis of the effects, the descriptive statistics are investigated. They can be observed in Fig 3.

Judging from Fig. 3, desktop display users were more accurate than the Gear VR users. Before comparing the accuracy of estimates on both platforms, their distributions were assessed with the Shapiro-Wilk normality test. The accurate estimates regarding the desktop display ($W = .584, p < .001$), Gear VR ($W = .489, p < .001$), with a scale ($W = .616, p < .001$), and not having a scale ($W = .458, p < .001$) did not follow Gaussian distribution. Therefore, the Wilcoxon rank sum test was used for comparison. The distances were compared between the platforms, and every difference was significant, except for 90 cm ($W = 20677, p = .140$). The remaining differences were strongly significant at each distance ($9103.5 \leq W \leq 36226, p \leq .002$).

Afterward, the effects of the scale were also compared. The accuracy was significantly different between the two groups ($W = 3169360, p < .001$). Those who used a scale were more accurate ($M = 0.382, SD = 0.486$) than those who did not ($M = 0.173, SD = 0.379$).

The last step was to assess the differences in accuracy regarding the three various objects. The Kruskal-Wallis rank sum test was used for this purpose. The results show that the various objects did not have significant effects on the results ($H(8) = 9.897, p = .272$), thus they were omitted from further analyses.

It should be noted that to conserve space, the following abbreviations are used in the forthcoming figures:

- M (Male),
- F (Female),
- DD (desktop display),
- GVR (Gear VR),
- LH (left-handed),
- RH (right-handed),
- Hx-y (height between x cm and y cm),
- G (wore glasses),
- NG (did not wear glasses),
- VGn-m (video game playtime per week between n and m hours),
- VRXP (previous VR experience),
- NVRXP (no previous VR experience).

A. Gender and display device

As was mentioned, the first part of the investigation focused on the effects of gender and display device. On PC, the skills of

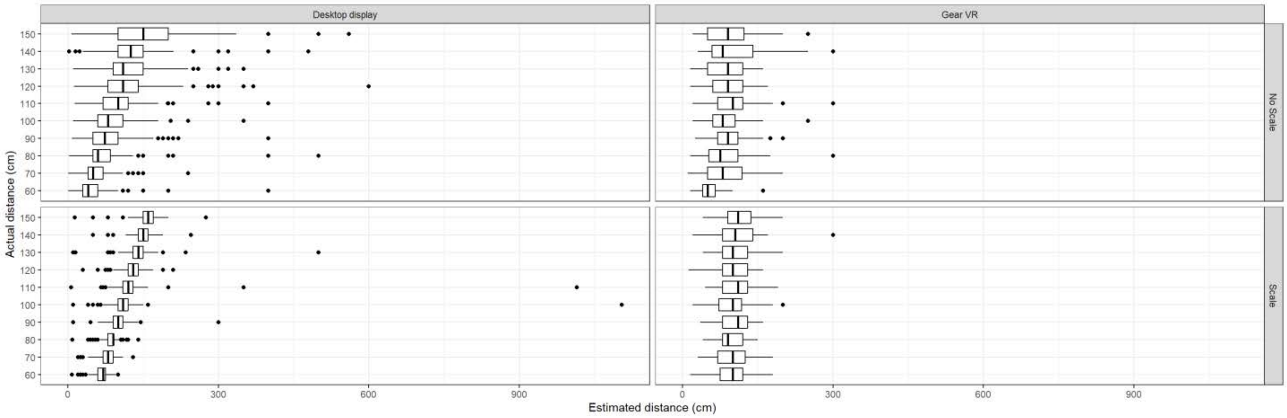


Fig. 3. Descriptive statistics of exocentric estimates on both display devices.

128 males and 29 females were measured. Contrarily, 49 males and 23 females used the Gear VR. The null-hypothesis was the following regarding this group: *The combination of gender, immersion level, and scale does not have a significant effect on the results.*

First, the accuracy of all possible combinations of groups was compared with the Kruskal-Wallis rank sum test. The results show significant differences between them ($H(7) = 407.6, p < .001$). Then, the probability of estimating accurately was compared using logistic regression analysis. The effects of each combination of variables can be seen in Figs. 4 and 5. The former presents the results when no scale was present, while the other shows them when the scale was present. In both cases, the basis variable was "female, desktop display".

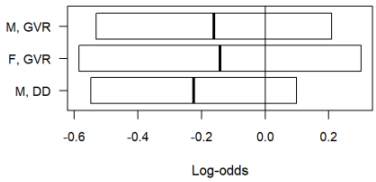


Fig. 4. 95% CIs showing the effects of the gender and display device pair when no scale was used.

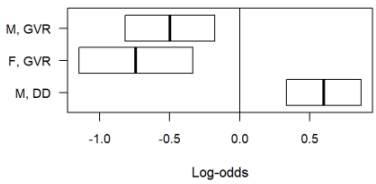


Fig. 5. 95% CIs showing the effects of the gender and display device pair when the scale was used.

When no scale was present, it can be observed that the investigated pairs of variables had no significant effects on the probability of accurate estimates. However, when the scale was present the likelihood of answering correctly significantly decreased in the case of both genders when the Gear VR was used. On average, males were less likely to answer accurately by 22.35%, while females were less likely to answer accurately by 17.53%. However, males were more likely to answer accurately by 67.07% on average, when they used the desktop display.

B. Dominant hand and display device

The following to investigate was the effects of the dominant hand and display device. On PC, the skills of 122 right-handed and 35 left-handed participants were measured. Contrarily, 67 and 5 used the Gear VR, respectively. Here, the null-hypothesis was the following: *The combination of dominant hand, immersion level, and scale does not have a significant effect on the results.*

As in the previous subsection, the accuracy of all possible groups was compared with the Kruskal-Wallis rank sum test. The results of the previously mentioned test showed significant differences between the accuracy of groups ($H(7) = 382.16, p < .001$). Afterward, the probability of estimating correctly was assessed. The results are shown in Figs. 6 and 7. Similarly, the former presents the results when no scale was present, while the other shows them when the scale was present. In both cases, the basis variable was "left-handed, desktop display".

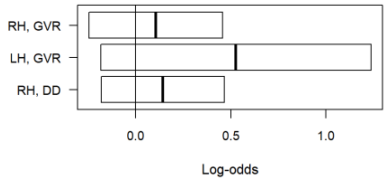


Fig. 6. 95% CIs showing the effects of the dominant hand and display device pair when no scale was used.

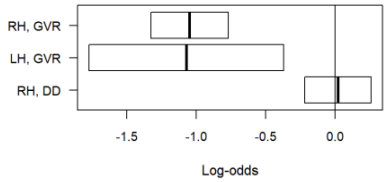


Fig. 7. 95% CIs showing the effects of the dominant hand and display device pair when the scale was used.

Similarly to gender and display device, the combination of dominant hand and display device had no significant effects on the accuracy of the participants when no scale was present. However, when the scale was present, those who used the Gear VR were less likely to accurately estimates distances. These likelihoods were 12.60% and 12.89% in the cases of left-handed and right-handed participants, respectively.

C. Height and display device

The effects of height and display device were investigated next. The distribution of students using one of each display device can be seen in Fig. 8. Here, the null-hypothesis was the following: *The combination of height groups, immersion level, and scale does not have a significant effect on the results.*

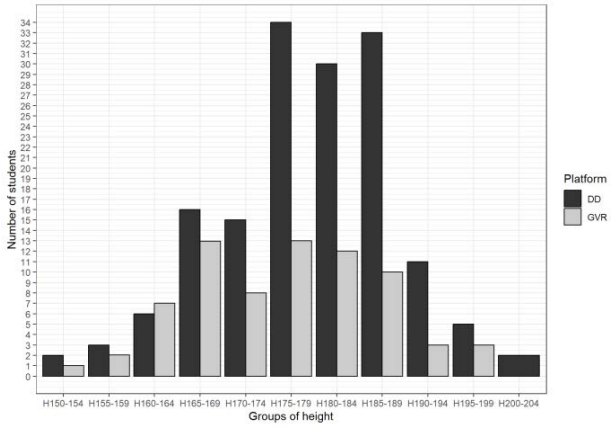


Fig. 8. Number of students using one of each display device, grouped by height.

First, as previously, the significant differences were assessed with the Kruskal-Wallis rank sum test. The results show that significant differences existed between the groups ($H(41) = 497.82, p < .001$). Next, the probability of accurate estimates was checked. The results can be seen in Figs. 9 and 10. Similarly to the previous subsections, the scale was

not present in the case of the former, while it was present in the case of the latter. In both cases, the basis variable was "height of 150-154 cm and desktop display".

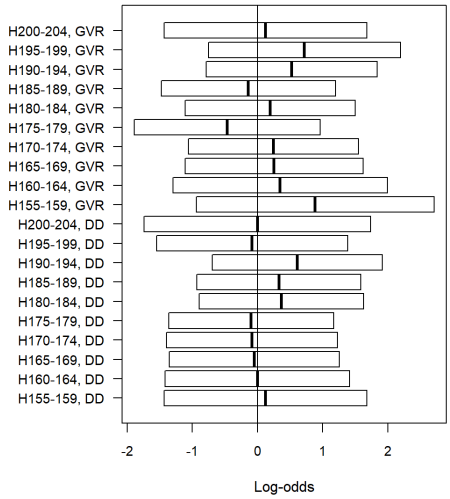


Fig. 9. 95% CIs showing the effects of the height groups and display device pair when no scale was used.

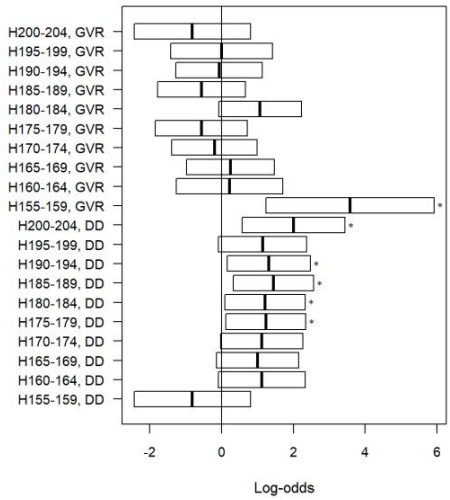


Fig. 10. 95% CIs showing the effects of the height groups and display device pair when the scale was used. To increase readability, significant effects were denoted by *.

As can be seen in Fig. 9., no significant effects were found when the scale was not present. Contrarily, Fig. 10 shows that there were six significant differences when the scale was present. Each of them had a larger likelihood of estimating accurately. These increases in the average likelihoods were observable in the following groups: H175-179, DD (126.24%); H180-184, DD (123.67%); H185-189, DD (156.34%); 190-194, DD (136.82%); H200-204, DD (273.28%); and H155-159, GVR (1324.36%). However, the larger increases may be due to the small number of participants in those groups.

D. Whether glasses were worn and display device

The next examination was the effects of glasses and display devices. There were 66 participants with glasses and 91 without them on PC, while these numbers were 33 and 39, respectively regarding to the Gear VR users. The null-hypothesis was the following regarding this group: *The combination of glasses, immersion level, and scale does not have a significant effect on the results.*

The Kruskal-Wallis rank sum test was used to assess whether there were significant differences between the possible combinations of groups. According to the results, significant differences exist between them ($H(7) = 383.63, p < .001$). Afterward, the effects on the probability of accuracy were investigated. The results are shown in Figs. 11 and 12. The former presents the results when no scale was present, while the latter shows them when the scale was present. In both cases, the basis variable was "wore glasses and desktop display".

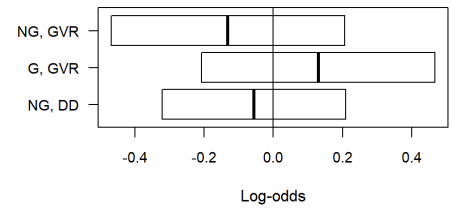


Fig. 11. 95% CIs showing the effects of the glasses and display device pair when no scale was used.

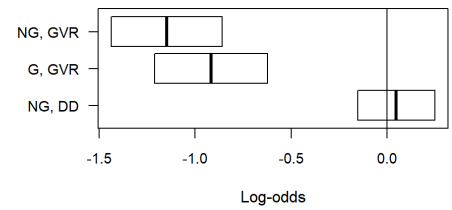


Fig. 12. 95% CIs showing the effects of the glasses and display device pair when the scale was used.

The results show that the use of the Gear VR significantly decreased the likelihood of answering correctly when the scale was used. In case of participants with glasses, the average decrease in likelihood was 14.71%, while that of those without glasses was 11.67%.

E. Video game playtime per week and display device

The effects of video game playtime (in hours) per week and display device were the next experiment. The distribution of students using both display devices can be seen in Fig. 13. Here, the null-hypothesis was the following: *The combination of video game playtime per week groups, immersion level, and scale does not have a significant effect on the results.*

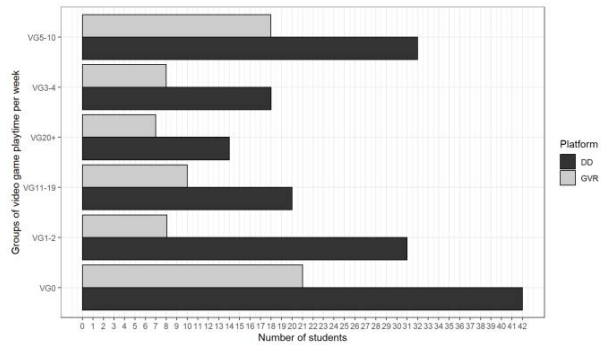


Fig. 13. Number of students using the display devices, grouped by video game playtime per week. The playtime is in hours.

Similarly, the Kruskal-Wallis rank sum test was used to assess the significant differences between the groups. The results show that there were significant differences between them ($H(23) = 425.05, p < .001$). Next, the effects on the probability of accurate estimates were investigated. The results can be observed in Figs. 14 and 15. The former presents the results when no scale was present, while the latter shows them when the scale was present. In both cases, the basis variable was "zero hours and desktop display".

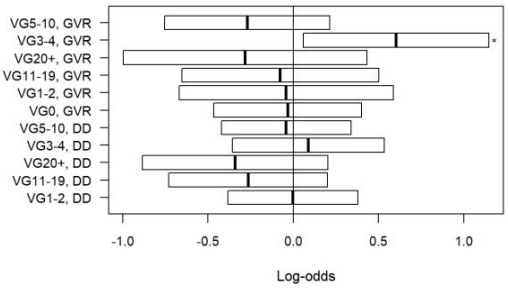


Fig. 14. 95% CIs showing the effects of the video game playtime per week groups and display device pair when no scale was used. To increase readability, significant effects were denoted by *.

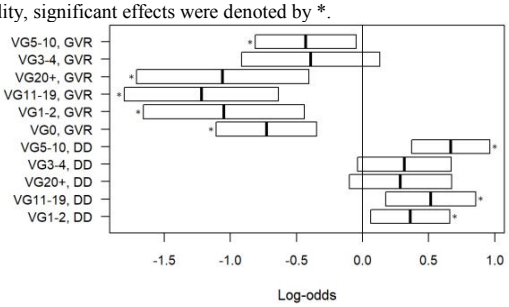


Fig. 15. 95% CIs showing the effects of the video game playtime per week groups and display device pair when the scale was used. To increase readability, significant effects were denoted by *.

Here, one significant effect could be found when no scale was present. The likelihood of the "VG3-4, GVR" group estimating correctly is significantly increased by 67.18% on average. When the scale was present, the likelihood significantly decreased in the case of five groups (VG5-10, GVR (23.88%); VG20+, GVR (12.75%); VG11-19, GVR (10.87%); VG1-2, GVR (12.87%); and VG0, GVR (17.76%)), and significantly increased in the case of three groups (VG5-10, DD (71.61%); VG11-19, DD (61.62%); and VG1-2, DD (52.77%)).

F. Previous VR experience and display device

The next to assess was the effects of the pair of previous VR experience and display devices. On PC, 57 participants had such experience, whereas 100 did not. Regarding the Gear VR users, 29 had such experience and 43 did not. Here, the null-hypothesis was the following: *The combination of previous VR experience, immersion level, and scale does not have a significant effect on the results.*

The possible groups were investigated with the Kruskal-Wallis rank sum test: there were significant differences between them ($H(3) = 253.18, p < .001$). Afterward, the probability of accurate estimates was investigated. The results can be observed in Figs. 16 and 17. The former presents the results when no scale was present, while the latter shows them when the scale was present. The basis variable was "no VR experience and desktop display" in both cases.

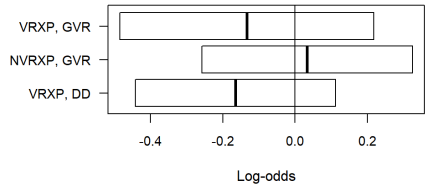


Fig. 16. 95% CIs showing the effects of the previous VR experience and display device pair when no scale was used.

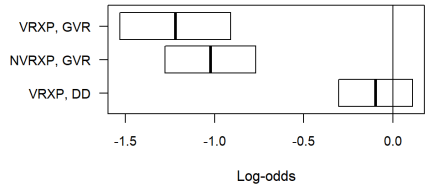


Fig. 17. 95% CIs showing the effects of the previous VR experience and display device pair when the scale was used.

There were no significant differences when no scale was used. However, when there was a scale in the VE, two significant decreases could be found in the likelihood of answering accurately. These occurred in the case of the VRXP, GVR (10.85%) as well as NVRXP, GVR (13.21%) groups.

G. Current studies and display device

The last to assess was the effects of the pair of current studies and display devices. There were 72 IT, 81 civil engineering, 27 mechanical engineering, and 49 vehicle engineering students. Here, the null-hypothesis was the following: *The combination of current studies, immersion level, and scale does not have a significant effect on the results.*

The accuracy of all possible groups was compared with the Kruskal-Wallis rank sum test. The results showed significant differences between the accuracy of groups ($H(7) = 384.15, p < .001$). Afterward, the probability of estimating correctly was assessed. The results are shown in Figs. 18 and 19. The former presents the results when no scale was present, while the other shows them when the scale was present. In both cases, the basis variable was "civil engineering, desktop display".

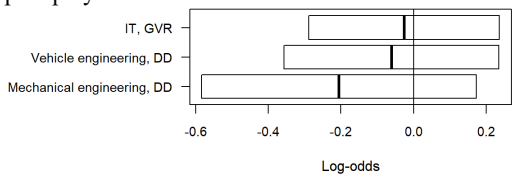


Fig. 18. 95% CIs showing the effects of the previous VR experience and display device pair when no scale was used.

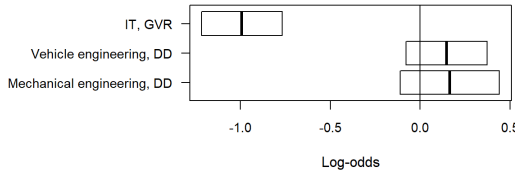


Fig. 19. 95% CIs showing the effects of the previous VR experience and display device pair when the scale was used.

In this case, there was only one significant decrease in the likelihood of estimating accurately. It is observable in the case of IT students who used the Gear VR (13.64%). However, it should be noted that it was with another display device compared to the others.

IV. Discussion

According to the findings, the research question was answered. In the literature, it is shown that display devices can influence distance estimation [24, 25, 27]. Combined with the immersion levels, every human characteristic had a significant effect on exocentric distance estimation when a scale was present. In the case of height and video game playtime per week, we did not find any patterns that could cause the significance in the differences.

It should also be noted that significant decreases in the likelihood of estimating correctly occurred with the Gear VR when the scale was present. This did not occur in the case of the desktop display. The results also show that the latter provided more accurate results and less deviation in the estimates.

As with every study, this one had limitations as well. The first limitation was the number of students with certain characteristics. For example, there were only five left-handed students on the Gear VR. Therefore, increasing the sample size could increase the value of the results as well. The second limitation was technological since we used the Gear VR head-mounted display. This device does not allow movement in 3D as it only follows the rotation of the user's head. By porting the Gear VR to PC as well and measuring with a newer head-mounted display could also produce more accurate results. The third limitation was the investigated distances. As was mentioned, the investigated distances were between 60 cm and 150 cm at 10 cm intervals. To provide a better understanding in the future, smaller or larger distances could be investigated. Since overestimation occurred at the investigated smaller distances, it would be interesting to study this trend at even smaller distances. Future research directions include studying the compositional elements in the VE, such as textures, lighting, and object size.

V. Conclusions

A VE was developed and the exocentric distance estimation skills of 229 students were assessed with it. Among them, 157 used a desktop display, whereas 72 used the Gear VR head-mounted display. During the measurements, several human characteristics were logged: gender; age; height; dominant hand; whether they wore glasses; their field of study; how many hours of video games they play per week; and whether they had any previous VR experience. After gathering the data, the statistical program package R was used for evaluation.

According to the results, when the human factors were combined with the display devices with various immersion levels, significant effects could be found. In almost all cases, significant effects only occurred when the scale was present. Therefore, based on these results, it is possible to conclude that while the desktop display was more accurate in exocentric distance estimation, the existence of a scale could change the probabilities of accurate exocentric distance estimates.

In conclusion, human factors combined with immersion level and a virtual scale have significant effects on exocentric distance estimation. Since both are integral components of VR systems, it is possible for them to interact with each other as shown by the results. These findings can be considered by developers when they design and implement new VEs to create a more accessible experience in the future.

Acknowledgment

Supported by the ÚNKP-23-4 New National Excellence Program of the Ministry for Culture and Innovation from the source of the National Research, Development and Innovation Fund.

This work has been implemented by the TKP2021-NVA-10 project with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the 2021 Thematic Excellence Programme funding scheme.

References

[1] C. L. Miller and G. R. Bertoline, "Spatial Visualization Research and Theories: Their Importance in the Development of an Engineering and Technical Design Graphics Curriculum Model", *Eng. Des. Graph. J.*, vol. 55, pp. 5–14, 1991.

[2] C. G. L. Cao, M. Zhou, D. B. Jones, and S. D. Schwaitzberg, "Can Surgeons Think and Operate with Haptics at the Same Time?", *J. Gastrointest. Surg.*, vol. 11, no. 11, pp. 1564–1569, 2007, DOI: 10.1007/s11605-007-0279-8

[3] R. B. Loftin, M. W. Scerbo, F. D. McKenzie, and J. M. Catanzaro, "Training in Peacekeeping Operations Using Virtual Environments", *IEEE Comput. Graph. Appl.*, vol. 24, no. 4, pp. 18–21, 2004, DOI: 10.1109/MCG.2004.21

[4] P. Baranyi and A. Csapo, "Definition and synergies of cognitive infocommunications", *Acta Polytech. Hung.*, vol. 9, pp. 67–83, 2012.

[5] G. Sallai, "The cradle of cognitive infocommunications"," *Acta Polytech. Hung.*, vol. 9, no. 1, pp. 171–181, 2012.

[6] P. Baranyi and A. Csapo, *Cognitive Infocommunications*. Springer International Publishing Switzerland.

[7] P. Baranyi, Á. Csapó, Á. Balázs, and P. Várlaki, "An Overview of Research Trends in CogInfoCom", in *18th International Conference on Intelligent Engineering Systems - INES* 2014, Tihany, 2014, pp. 181–186, DOI: 10.1109/INES.2014.6909365

[8] C. Vogel and A. Esposito, "Interaction Analysis and Cognitive Infocommunications," *Infocommunications J.*, vol. 12, no. 1, pp. 2–9, 2020, https://doi.org/10.36244/ICJ.2020.1.1

[9] A. Torok, "From human-computer interaction to cognitive infocommunications: A cognitive science perspective," in *2016 7th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, 2016, pp. 000 433–000 438, DOI: 10.1109/CogInfoCom.2016.7804588

[10] I. Horváth, A. B. Csapó, B. Berki, A. Sudár, and P. Baranyi, "Definition, Background and Research Perspectives Behind 'Cognitive Aspects of Virtual Reality' (cVR)," *Infocommunications J., Special Issue: Internet of Digital & Cognitive realities*, pp. 9–14, 2023, DOI: 10.36244/ICJ.2023.SI-IODCR.2

[11] A. Lele, "Virtual reality and its military utility," *J. Ambient Intell. Humaniz. Comput.*, vol. 4, no. 1, pp. 17–26, 2013, DOI: 10.1007/s12652-011-0052-4

[12] N. E. Seymour, A. G. Gallagher, S. A. Roman, M. K. O'Brien, V. K. Bansal, D. K. Andersen, and R. M. Satava, "Virtual reality training improves operating room performance: Results of a randomized, double blinded study," *Ann. Surg.*, vol. 236, no. 4, pp. 458–464, 2002, DOI: 10.1097/00000658-200210000-00008

[13] J. Psotka, "Immersive training systems: Virtual reality and education and training," *Instr. Sci.*, vol. 23, no. 5–6, pp. 405–431, 1995, DOI: 10.1007/bf00896880

[14] L. Freina and M. Ott, "A Literature Review on Immersive Virtual Reality in Education: State of the Art and Perspectives," *Int. Sci. Conf. Elearning Softw*, vol. 1, pp. 10–18, 2015.

[15] M. Zyda, "From visual simulation to virtual reality to games," *Computer (Long Beach Calif.)*, vol. 38, no. 9, pp. 25–32, 2005, DOI: 10.1109/mc.2005.297

[16] J. Bates, "Virtual reality, art, and entertainment," *Presence (Camb.)*, vol. 1, no. 1, pp. 133–138, 1992, DOI: 10.1162/pres.1992.1.1.133

[17] F. E. Jamiy and R. Marsh, "Distance estimation in virtual reality and augmented reality: A survey," in *2019 IEEE International Conference on Electro Information Technology (EIT)*, 2019, pp. 63–68. DOI: 10.1109/EIT.2019.8834182

[18] R. V. Kenyon, M. Phenany, D. Sandin, and T. Defanti, "Accommodation and size-constancy of virtual objects," *Ann. Biomed. Eng.*, vol. 36, no. 2, pp. 342–348, 2008, DOI: 10.1007/s10439-007-9414-7

[19] S. H. Creem-Regehr, J. K. Stefanucci, and B. Bodenheimer, "Perceiving distance in virtual reality: theoretical insights from contemporary technologies," *Philos. Trans. R. Soc. Lond. B Biol. Sci.*, vol. 378, no. 1869, 2023. DOI: 10.1098/rstb.2021.0456

[20] A. Murgia and P. M. Sharkey, "Estimation of distances in virtual environments using size constancy," *Int. J. Virtual Real.*, vol. 8, no. 1, pp. 67–74, 2009, DOI: 10.20870/ijvr.2009.8.1.2714

[21] J. S. Lappin, A. L. Shelton, and J. J. Rieser, "Environmental context influences visually perceived distance," *Percept. Psychophys.*, vol. 68, no. 4, pp. 571–581, 2006, DOI: 10.3758/bf03208759

[22] F. El Jamiy, A. N. Ramaseri Chandra, and R. Marsh, "Distance accuracy of real environments in virtual reality head-mounted displays," in *2020 IEEE International Conference on Electro Information Technology (EIT)*, 2020, pp. 281–287. DOI: 10.1109/EIT48999.2020.9208300

[23] B. J. Mohler, S. H. Creem-Regehr, W. B. Thompson, and H. H. Bülthoff, "The effect of viewing a self-avatar on distance judgments in an HMD-based virtual environment," *Presence (Camb.)*, vol. 19, no. 3, pp. 230–242, 2010, DOI: 10.1162/pres.19.3.230

[24] A. Naceri, R. Chellali, and T. Hoinville, "Depth perception within peripersonal space using head-mounted display," *Presence (Camb.)*, vol. 20, no. 3, pp. 254–272, 2011, https://doi.org/10.1162/pres_a_00048

[25] R. S. Renner, B. M. Velichkovsky, and J. R. Helmert, "The perception of egocentric distances in virtual environments – A review," *ACM Comput. Surv., vol.* 46, no. 2, pp. 1–40, 2013, DOI: 10.1145/2543581.2543590

[26] J. W. Kelly, "Distance perception in virtual reality: A meta-analysis of the effect of head-mounted display characteristics," *IEEE Trans. Vis. Comput. Graph.*, vol. 29, no. 12, pp. 4978–4989, 2023. DOI: 10.1109/tvcg.2022.3196606

[27] T. Guzsvinecz, E. Perge, and J. Szűcs, "Examining the results of virtual reality-based egocentric distance estimation tests based on immersion level," *Sensors (Basel)*, vol. 23, no. 6, p. 3138, 2023, DOI: 10.3390/s23063138

[28] X. Luo, R. V. Kenyon, D. G. Kamper, D. J. Sandin, and T. A. DeFanti, "On the determinants of size-constancy in a virtual environment," *Int. J. Virtual Real.*, vol. 8, no. 1, pp. 43–51, 2009, DOI: 10.20870/ijvr.2009.8.1.2712.

[29] C. Armbrüster, M. Wolter, T. Kuhlen, W. Spijkers, and B. Fimm, "Depth perception in virtual reality: Distance estimations in Peri- and extrapersonal space," *Cyberpsychol. Behav.*, vol. 11, no. 1, pp. 9–15, 2008, DOI: 10.1089/cpb.2007.9935

[30] C. Saracini, M. Olivetti Belardinelli, A. Hoepfner, and D. Basso, "Differences in Distance Estimations in Real and Virtual 3D Envi-ronments," in *Proceedings of the 2nd International and Interdisciplinary Conference on Image and Imagination*, Alghero, Italy; Cham, Switzerland: Springer International Publishing, 2019, pp. 881–896.

[31] H. Coelho, M. Melo, F. Branco, J. Vasconcelos-Raposo, and M. Bessa, "The impact of gender, avatar and height in distance perception in virtual environments," in *Advances in Intelligent Systems and Computing, Cham: Springer International Publishing*, 2019, pp. 696–705, DOI: 10.1007/978-3-030-16184-2_66

[32] I. T. Feldstein, F. M. Kölsch, and R. Konrad, "Egocentric distance perception: A comparative study investigating differences between real and virtual environments," *Perception*, vol. 49, no. 9, pp. 940–967, 2020. DOI: 10.1177/0301006620951997

[33] T. Guzsvinecz, E. Perge, and J. Szűcs, "Analyzing accurate egocentric distance estimates of university students in virtual environments with a desktop display and Gear VR display," *Electronics (Basel)*, vol. 12, no. 10, p. 2253, 2023, DOI: 10.3390/electronics12102253

[34] G. Burdea and P. Coiffet, *Virtual Reality Technology*. Nashville, TN: John Wiley & Sons, 2003.

[35] V. Kövecses-Gősi, "Cooperative learning in VR environment," *Acta Polytech. Hung.*, vol. 15, no. 3, 2018, DOI: 10.12700/aph.15.3.2018.3.12

Tibor Guzsvinecz is an Assistant Professor at the Faculty of Information Technology of the University of Pannonia, Hungary. He obtained his PhD degree in the field of Information Science in 2021. His research areas are data science, gamification, human-computer interaction, spatial ability, and virtual reality. He authored 105 scientific publications which include 32 journal papers, and 59 studies found in various conference proceedings. At the moment, he is an editor of two book projects: about gamification and one about game theory. He is an IEEE member since 2023.

Judit Szűcs is an Assistant Professor at the Faculty of Information Technology of the University of Pannonia, Hungary. She received her PhD degree in 2021 in Computer Science at the University of Szeged. Her main interests include binary tomography, image processing, and computer vision. She has 56 scientific publications which include 15 journal papers, and 38 studies found in various conference proceedings. She is an IEEE member since 2023.

Erika Perge is an Assistant Professor at the Department of Basic Technical Studies, Faculty of Engineering, University of Debrecen, Hungary. She is a qualified instructor of computer science, mathematics and drawing. She earned her PhD in mathematics and computer science in 2018. Her research areas are the following:spatial ability, color perception ability and didactics. She has authored 58 scientific publications: 18 journal papers, 2 books, 4 book chapters, 15 conference papers and 19 other scientific works. She has been a member of the public body of the Hungarian Academy of Sciences since 2018. Since 2020, she has also been a member of the John von Neumann Computer Society and the Hungarian Society for Geometry and Graphics, the Hungarian branch of the International Society for Geometry and Graphics (ISGG).

Learning 3D Computer-Aided Design on Immersive Platforms of Augmented and Virtual Reality

Chenxin Wu, Mengjie Huang, Rui Yang, Zhaoyu Xu, Wenxin Sun, and Liu Wang

***Abstract*—In an era of rapidly evolving educational paradigms, the field of education is challenged by participation and the integration of innovative technologies. This study, therefore, introduces a novel learning platform for 3D Computer-Aided Design education, integrating Augmented Reality (AR) and Virtual Reality (VR) to enhance traditional educational methods and perhaps provide new sights for the direction of practice. It proposes three key features: Campus Exploration, 3D Modeling Instruction, and Modeling Rewards, each tailored to different phases of the learning process. The platform aims to improve learner motivation, user experience, and engagement through immersive technologies. A user study involving twenty participants compared the subjective experience of AR and VR interfaces against traditional teaching methods. The findings indicate that immersive platforms, especially AR, significantly enhance learning experiences compared to conventional methods. AR's integration with the real environment and its user-friendly nature, coupled with the portability of handheld devices, contribute to its superiority over VR in educational settings. This study underscores the potential of AR in 3D modeling education, suggesting that its incorporation into educational frameworks can profoundly impact learning outcomes. The research highlights the need for innovative educational models that incorporate immersive technologies to foster a more engaging and effective learning environment.**

***Index Terms*—learning, 3D modeling, augmented reality, virtual reality, computer-aided design**

I. Introduction

In the landscape of traditional educational methodologies, educators frequently gravitate towards purpose-driven strategies, often culminating in an over-standardization of teaching methods. This tendency towards uniformity can inadvertently dampen student enthusiasm and impinge upon the efficacy of conventional pedagogical approaches [1]. Concurrently, the burgeoning trend of assisted learning concepts [2] has spurred educators to explore the integration of assistive tools. These tools aim to invigorate student engagement and enhance the learning experience, thus spotlighting the necessity for more innovative educational models [3]-[5]. Within traditional learning environments for 3D Modeling in Computer-Aided Design (CAD), the reliance on theoretical knowledge and case demonstrations is prevalent, aiding beginners to rapidly immerse in the educational process. However, the escalating influence of immersive technologies, such as augmented reality (AR) and virtual reality (VR), fueled by their growing accessibility and prevalence, is reshaping educational paradigms [6]. Notably, AR aligns with situated learning theory [7], while VR resonates with the constructivist learning approach [8]. Each, though distinct in its emphasis, is poised to offer enriched learning experiences [7][8]. Especially in the education context of CAD, as AR and VR also utilize the techniques of 3D modeling for developing 3D models and environments, they possess a strong link with CAD and can serve as an immersive assistant in its learning. Despite their apparent potential, the pragmatic application of these technologies in educational settings requires further exploration.

Addressing this gap, this study introduces an assisted learning platform for 3D modeling underpinned by immersive technologies and characterized by three principal features that draw on the concept of gamified learning: Campus Exploration, 3D Modeling Instruction, and Modeling Rewards. This innovative platform integrates two pivotal immersive technologies, AR and VR, tailoring their application across the three critical phases of the modeling learning process in CAD: preparatory, active, and concluding phases. This approach is designed to yield substantial benefits for learners, particularly in enhancing user motivation, experience, and other subjective dimensions. Through conducting comprehensive user research, this study endeavors to ascertain the interactive assistance provided by these immersive technologies in the learning process. Additionally, this study elucidates the subjective variances between AR and VR when integrated within traditional educational frameworks, thereby offering a nuanced understanding of their respective impacts on the educational experience. This exploration is pivotal in charting new trajectories in educational technology and pedagogy, particularly in the realm of 3D CAD. This article contributes significantly to the field in several ways:

- This study presents an original assisted learning platform for 3D CAD that synergistically combines AR and VR technologies, providing a novel approach to modeling education.
- This study offers empirical insights into the comparative effectiveness of immersive technologies in enhancing the learning process, bridging a critical research gap in the

This work was supported by the Teaching Development Fund of Xi'an Jiaotong-Liverpool University (TDF21/22-R23-164). Corresponding author: Mengjie Huang (e-mail: mengjie.huang@xjtlu.edu.cn),

C. Wu, Z. Xu and R. Yang are with the School of Advanced Technology, Xi'an Jiaotong-Liverpool University, Suzhou, China.

M. Huang is with the Design School, Xi'an Jiaotong-Liverpool University, Suzhou, China.

W. Sun and L. Wang are with the Design School, Xi'an Jiaotong-Liverpool University, Suzhou, China and the School of Engineering, University of Liverpool, Liverpool, United Kingdom.

DOI: 10.36244/ICJ.2025.6.5

application of immersive technologies in education.
- This study highlights the subjective differences between immersive technologies and traditional teaching methods, offering valuable perspectives for educators and policymakers in curriculum development.

II. Literature Review

A. Augmented Reality in Learning

AR is regarded as a revolutionary technique, that seamlessly integrates virtual content with the physical world, offering learners a unique spatial experience. This fusion has profound implications in educational spheres, where AR has risen as a formidable tool [9][10]. Studies have delved into the theoretical foundations of AR in education, examining constructivist learning theories and AR's potential [11]. Particularly in elementary education, AR has demonstrated its ability to enhance learning, especially in comprehending abstract scientific concepts. Initial research suggests AR's interactive nature makes complex topics more accessible and intriguing for young students [12]. Beyond primary education, AR's role in tertiary learning environments has been extensively examined. Studies underscore its efficacy in enriching academic experiences across disciplines [13]. AR provides immersive and interactive environments that help deepen students' comprehension and retention of information. Additionally, AR's impact in special education is gaining focus; its customization potential can significantly improve learning outcomes in specialized educational settings [14].

Despite these advantages, integrating AR into education faces challenges. Developing AR content and ensuring a high-quality user experience are substantial obstacles [15]. The demand for AR technology tailored for individualized learning, along with the need to balance complex and general subject matter, presents additional difficulties. These challenges are not solely technical but also pedagogical, necessitating a delicate balance between AR technological advancements and educational efficacy [16]. In sum, while AR offers transformative potential in educational contexts, its successful adoption hinges on overcoming these prevalent challenges [17]. Addressing these issues is critical for AR to revolutionize the educational landscape, making learning more immersive, accessible, and effective [15] [17].

B. Virtual Reality in Learning

VR technology has markedly revolutionized the interaction between users and digital content. With the utilization of controllers and head-mounted displays, VR offers an immersive experience, enabling profound engagement with virtual environments [18] [19]. This advancement has notably influenced the education sector, bolstering student engagement and fostering innovative thinking [20]. The introduction of VR as an immersive educational tool has sparked significant academic discourse, exploring its varied effects across different educational levels and fields. In educational contexts, VR's application is distinguished by its capacity to create dynamic and interactive learning spaces. These environments are designed to captivate students' attention and stimulate their creativity, thereby enhancing the effectiveness and engagement of learning processes [21]. Particularly, VR's ability to replicate intricate real-world scenarios provides a hands-on learning approach, improving comprehension, information retention, and fostering active learning and critical thinking skills [22]. However, the incorporation of VR in education is not without challenges. Issues such as high costs, the need for specialized equipment, and the risk of motion sickness in some users present notable obstacles [23]. Furthermore, a lack of high-quality, VR-specific educational content hinders the technology's educational potential [24].

Empirical studies, though, have demonstrated VR's positive influence on learning outcomes. Research indicates that VR can surpass traditional teaching methods by enhancing student performance, increasing engagement, and deepening emotional involvement [25]. Its immersive and interactive nature makes abstract and complex concepts more tangible and comprehensible, thus improving learning experiences [26]. An essential aspect of VR's educational discourse includes its integration into pedagogy and curriculum adaptation. It's crucial to address how VR supplements traditional teaching methods and the training educators require to efficiently implement VR technology in classrooms [27].

C. The Comparison between AR and VR

Immersive technologies, notably AR and VR, have become pivotal in various fields such as healthcare, entertainment, and education, gaining significant traction in modern society [28]-[30]. Numerous studies have focused on comparing AR and VR in different application scenarios, revealing varied outcomes. In education, a study employing the ARCS model for motivational design compared the effects of websites, AR, and VR on learning motivation [31]; this research found that VR excelled in promoting attention, relevance, and confidence, whereas AR was superior in terms of learner satisfaction. Despite these findings, there remains a research gap in the detailed comparison of AR and VR within the educational context [32]. In other domains, the distinction between AR and VR has been a subject of interest. For instance, one study explored the differences in agoraphobic environments and showed that both AR and VR can induce anxiety or fear at the right time in virtual environments, but there was no statistical difference [33]. In a study involving children tasked with object counting, no major difference in objective outcomes was found between AR and VR, though AR was more popular [34]. The healthcare sector has also seen comparisons between these technologies. Besides, VR's advanced visualization capabilities have been found more favorable among medical professionals compared to AR, suggesting a preference for VR in certain professional applications [35].

Overall, AR and VR can't be shown to be overwhelmingly superior under any circumstances. The efficacy of these technologies is highly context-dependent and varies with each specific use case. This situation emphasizes the importance of a detailed comprehension of the distinct advantages and limitations of immersive techniques, ensuring their application

is tailored to fit the unique needs and circumstances of each scenario [36]. Recognizing and leveraging the unique qualities and capabilities of each technology is essential, rather than relying on a one-size-fits-all approach, to optimize their impact and utility in a variety of environments [37].

III. Framework Design

Traditional 3D modeling education, focused on foundational theories and manual practices, has effectively met learners' needs through hands-on operations and experiential learning [38]. However, technological advancements are reshaping this field, with digital modeling and CAD emerging as significant forces. This shift reflects a growing interest among learners in using emerging technologies for skill development in 3D modeling. Immersive technologies have evolved into powerful educational tools, offering significant contributions across various academic fields [39]. Decreasing costs and increasing accessibility have led to their experimental use in education [39]. This paper introduces a novel learning platform tailored for beginners in 3D modeling, integrating immersive technologies such as AR and VR. Centered around virtual campus environments, it aims to bridge the gap between conventional modeling education and the evolving demands of modern learning environments. These tools are instrumental in providing a comprehensive understanding of modeling techniques and enhancing learner enthusiasm.

A. Framework Features

This pedagogical framework for 3D modeling education follows a sequential structure: a preparatory phase before learning, an active learning phase, and a concluding phase with rewards. It integrates three main components: Campus Tour, 3D Modeling Instruction, and Modeling Rewards. Designed to progressively build interest and motivation, this gamified approach enhances understanding of spatial relationships in 3D models. Incorporating immersive technologies, it aims to improve learners' perceptual and interactive experiences, potentially enriching the learning environment and positively impacting educational outcomes.

Fig. 1. Framework features

Campus Tour: In the proposed learning platform, the "Campus Tour" feature forms a foundational component, acting as a critical gateway to the learning platform. This initial stage is designed to captivate learners' curiosity and bolster their motivation, setting a robust foundation for the subsequent stages of the learning process. The campus landscape of the learner's university, meticulously reimagined and reconstructed in digital form, is presented as a series of intricate 3D models within virtual environments (Fig. 2). This digital representation is not merely a static replication; it is enriched with interactive and functional elements, integrating immersive technologies to create a multifaceted virtual campus experience. Before embarking on their educational journey of 3D modeling, learners are invited to immerse themselves in this virtual campus. Here, they are not mere spectators but active participants, exploring the intricacies of the campus through the corresponding system. One of the most notable features of this tour is the opportunity to observe and understand the modeling history of various campus structures. This exposure to the evolution and techniques involved in 3D modeling provides a context-rich pre-learning experience, laying an attractive groundwork for their subsequent educational endeavors. In the immersive settings, learners navigate the virtual campus using head-mounted devices (HMDs) within the VR interface, offering a fully immersive experience. In contrast, the AR interface is accessed through handheld devices, overlaying digital information onto the physical world, thereby providing a different but equally enriching experience. This innovative mode of campus touring extends beyond mere novelty; it serves as a powerful assistive tool for learning 3D modeling. By allowing learners to traverse the historical timeline of model creation of campus structures, it fosters an initial and intuitive understanding of 3D modeling process. This experiential learning approach is pivotal in stimulating learners' interest and reinforcing their motivation. It offers a preliminary glimpse into the world of 3D modeling, subtly introducing the thought processes and the outcomes behind it.

Furthermore, the Campus Tour embodies the principle of "learning by exploration", a pedagogical approach that encourages learners to construct their understanding through active engagement. By navigating the virtual campus, learners are not just passive recipients of information but are actively constructing knowledge, an experience that resonates more profoundly than traditional didactic methods. This feature of the platform is instrumental in assisting conventional teaching paradigms, shifting the focus from teacher-centered instruction to learner-centered exploration.

3D Modeling Instruction: The "3D Modeling Instruction" component, integral to the learning platform, functions as an essential adjunct to traditional modeling education, enriching rather than replacing the established teaching methodologies. This module strategically blends with the conventional curriculum, offering an immersive and interactive dimension that enhances the overall learning experience. Central to this innovative approach is the virtual modeling workstation, where learners engage with 3D models in a dynamic virtual environment. This hands-on interaction facilitates a deep and practical understanding of the entire modeling process. The module is further enhanced by its unique guidance methods, including textual instructions and strategic highlights. These features offer real-time, tailored advice and tips, significantly augmenting the learning process. It's crucial to recognize that

this technology-enhanced instruction is intended to supplement, not supplant, traditional modeling teaching methods. The experiential learning provided by manual practices and face-to-face teaching remains indispensable. The 3D Modeling Instruction module aims to bridge the theoretical and practical aspects of modeling, thus providing a more holistic educational experience. This instructional method is designed to be universally applicable, catering to learners at various stages of the modeling process. From beginners grappling with basic shapes to more advanced learners dealing with complex structures, the system offers tailored support, making it an inclusive and adaptable learning tool. This feature is especially advantageous for beginners who require foundational guidance, ensuring that learners can progress at their own pace, building confidence and competence as they advance.

Moreover, the module's indirect benefits extend beyond skill acquisition in modeling. Engaging with 3D models in a virtual setting enhances learners' spatial awareness and visualization skills, which are broadly applicable and valuable. This approach also aligns with active learning and constructivist educational theories, promoting learners as active participants in their educational journey.

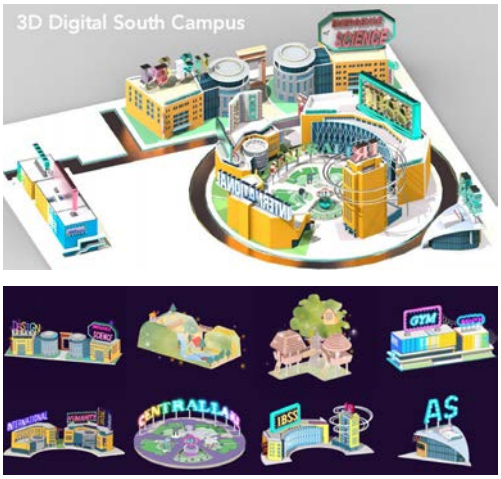


Fig. 2. Campus Model (top) and Modeling Reward (bottom)

Modeling Rewards: Within the innovative framework of the learning platform, the "Modeling Rewards" component encapsulates the concept of post-learning reward feedback, a fundamental aspect that aligns seamlessly with the principles of gamified learning. Gamification in education is a burgeoning field, recognized for its effectiveness in enhancing learner motivation and user experience through reward-based feedback mechanisms [41]. This approach significantly encourages learners to persevere and succeed in their subsequent learning tasks. Upon the successful completion of specific modeling tasks, students are awarded 2D graphic fragments corresponding to the model they have worked on (Fig. 2). These fragments are not merely symbolic achievements; they are designed to integrate into the learners' personalized settings, offering a tangible sense of progress and accomplishment. The accessibility of these rewards is a key feature, with the distribution of the 2D fragments designed to be easily retrievable through common electronic devices, ensuring that learners can view and appreciate their achievements with ease. In parallel to the reimagined 3D virtual campus, these 2D modeling fragments are artistically stylized. This stylistic enhancement is not just an aesthetic choice but a deliberate strategy to bolster learners' motivation to collect and cherish these rewards. The allure of these visually appealing fragments adds an additional layer of engagement to the learning process, making the acquisition of new skills both rewarding and enjoyable. The gamification aspect of the Modeling Rewards extends beyond mere engagement. It emerges as an effective pedagogical tool for instructors, enabling them to supplement traditional teaching methods and track course progress through a novel, interactive lens. This innovative integration of rewarding mechanisms into the educational framework represents a forward-thinking approach to reinforcing learning outcomes. It skillfully blends traditional educational techniques with modern, interactive elements, creating a dynamic, engaging, and more effective learning environment.

Besides, the introduction of such a rewarding system in the learning process is underpinned by psychological principles of reinforcement and motivation. When learners receive positive reinforcement in the form of these rewards, it not only acknowledges their efforts but also stimulates the intrinsic motivation to continue exploring and learning. This aspect is particularly effective in educational settings where sustaining student engagement and motivation can be challenging [41]. Modeling reward characteristics is a reflection of educational psychology.

In summary, the platform skillfully incorporates three key features, including Campus Tour, 3D Modeling Instruction, and Modeling Rewards, as supplementary aids to traditional teaching methods in modeling education. Campus Tour serves as an engaging pre-learning experience, utilizing AR and VR for explorative understanding. 3D Modeling Instruction feature enriches the learning process by providing interactive, virtual assistance in mastering modeling techniques. Finally, Modeling Rewards will motivate and acknowledge learners' progress. Together, these features enhance and aid traditional educational methods, providing an additional, interactive dimension to learning while complementing teaching and learning.

B. Development Tools

The development of this system is grounded in the use of Unity, a versatile platform renowned for its capacity to integrate diverse technologies such as AR, VR, Web, and User Interface (UI) techniques. In crafting the AR component, the system employs the Vuforia plugin, which facilitates desktop scanning and seamlessly integrates with the UI system and AR Foundation, culminating in a comprehensive AR experience. This functionality is optimized for deployment on handheld devices, like Mobile Phones (iPhone 15). In contrast, the VR dimension utilizes OpenXR, ensuring compatibility and high performance on HMDs like the Oculus Quest 2.

IV. User Study

Upon the completion of the framework design integrating AR and VR platforms with traditional teaching methodologies for 3D modeling, a user study was initiated to examine the subjective experiences of participants utilizing these platforms. This study was conducted at the authors' university, and involved a diverse group of twenty students, encompassing undergraduates, graduates, and doctoral candidates, all of whom lacked prior experience in modeling. Prior to commencing the experiment, basic information regarding the user study was provided to each volunteer, and their informed consent was obtained through signed consent forms.

A. Experiment Setup

The experiment of this user study was setup to evaluate the integration of AR and VR platforms with traditional teaching methods in 3D modeling education. Utilizing two distinct platforms: the AR platform operated on handheld devices (iPhone 15 Pro) and the VR platform on HMDs (Oculus Quest 2). The study aimed to explore the learners' subjective responses with these immersive technologies alongside traditional instruction. Twenty participants, aged 20 to 30, were recruited for the study. To ensure a comprehensive evaluation, the study adopted a within-subject design, where participants were assigned to two groups, each experiencing both AR and VR platforms in conjunction with traditional teaching methods.

Fig. 3. Campus tour in AR settings

Fig. 4. Campus tour in VR settings

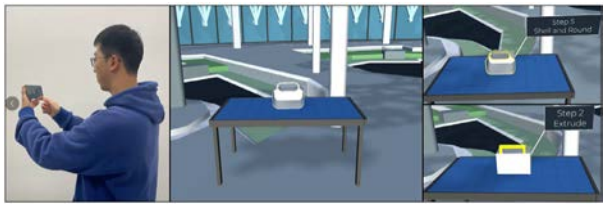


Fig. 5. 3D modeling instruction in AR settings

Fig. 4. 3D modeling instruction in VR settings

To ensure a thorough assessment, the study encompassed several phases in the experiment. In the first phase, participants were allowed to experience a full course of modeling instruction on a computer, including instructional videos and PowerPoint presentations. Immediately after, in the second phase, depending on the grouping, participants are guided to the virtual campus to visit the virtual campus and explore the modeling process of campus buildings in an AR or VR platforms (Fig. 3 and Fig. 4). This phase was crucial for them to familiarize themselves with the platform and future tasks. Subsequently, in the third phase, participants were allowed to conduct the 3D modeling guidance functions at the virtual modeling table in the AR or VR setup for the content told in the traditional course (Fig. 5 and Fig. 6), providing practical insights into the results of the platform. In turn, the content carried out in phases 2 and 3 will be repeated in phases 4 and 5 on another platform based on the group arrangement.

B. Measurements & Discussion

In this study, self-report evaluations were conducted at the end of the first, third and fifth phases of the experiment through Questionnaire A to compare traditional teaching methods with two immersive platforms, specifically focusing on four dimensions of subjective experience, as shown in Table I. The results, based on self-reported outcomes presented in Fig. 7, are discussed below in the context of each dimension.

TABLE I
Questionnaire A

Overall experience	I feel it is easy to learn 3D modeling with this learning method.
	I feel it is interesting to learn 3D modeling with this learning method.
	I feel it is effective to learn 3D modeling with this learning method.
Confidence	I am confident to accomplish similar 3D modeling task after learning.
Motivation	I become more interested in 3D modeling task after learning.
Satisfaction	I am satisfied with this learning method.

1) Overall Experience: Figure 7(i) reveals that while there was no significant difference between the immersive platforms regarding overall experience, a marked contrast was noted between traditional teaching and both AR ($\chi^2=7.39$, $p=0.0065$) and VR ($\chi^2=4.95$, $p=0.0259$). Notably, the immersive platforms scored significantly higher than traditional teaching ($M=0.6$), with AR ($M=1.97$) slightly outperforming VR ($M=1.73$). This suggests that while both AR and VR enhance the learning experience compared to traditional methods, AR may offer a marginally more engaging overall experience.

2) Confidence: As depicted in Figure 7(ii), no significant differences were observed in confidence levels between traditional teaching and the immersive platforms, nor between AR and VR. However, the average scores indicate a trend where the AR platform scored the highest ($M=2.15$), followed by VR ($M=1.65$), and traditional teaching the lowest ($M=1.15$). This suggests that while not statistically significant, immersive platforms may instill a higher sense of confidence in learners compared to traditional methods.

3) Motivation: Significant disparities were identified in motivation levels, as shown in Figure 7(iii). A notable difference was observed between the immersive platforms ($\chi^2=8.09$, $p=0.0045$), and both AR ($\chi^2=19.78$, $p<0.0001$) and

VR (χ^2=7.28, p=0.007) significantly outperformed traditional teaching. AR once again scored highest (M=2.6), followed by VR (M=1.55), and traditional teaching scored substantially lower (M=0.15). This indicates a clear motivational advantage for immersive platforms, particularly AR.

4) Satisfaction: Figure 7(iv) indicates no significant differences in satisfaction between AR and VR platforms. However, both AR (χ^2=8.41, p=0.0037) and VR (χ^2=4.07, p=0.0435) demonstrated significant improvements over traditional teaching. The overall satisfaction scores were notably higher for the immersive platforms than for traditional teaching (M=0.5), with AR (M=2.1) leading over VR (M=1.5). This suggests that while both platforms enhance satisfaction, AR might provide a slightly more satisfying experience.

The results indicate that while AR and VR platforms offer no significant differences in some aspects, they both significantly enhance the overall experience, motivation, and satisfaction of learners compared to traditional teaching methods. AR, in particular, seems to offer a slight edge over VR in these areas. This study underscores the potential of immersive technologies to augment traditional educational approaches, providing a more engaging, confidence-boosting, and satisfying learning environment.

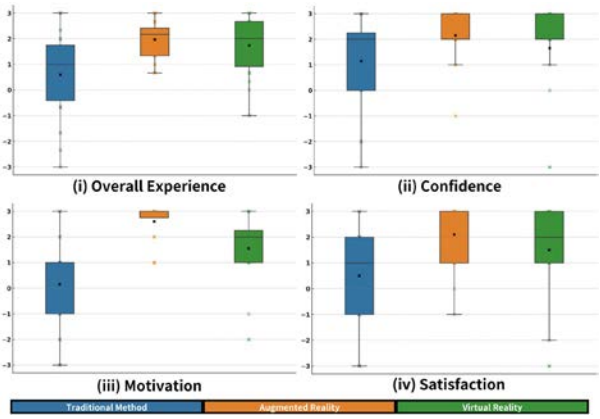


Fig. 5. Self report results of Questionnaire A

Additionally, after the third and fifth phases of the experiment, the performance of two critical features: learning motivation related to the Campus Tour and learning effectiveness associated with 3D Modeling Instruction, were scrutinized through self-reports with Questionnaire B (Table II). Participants were also required to fill in the User Experience Questionnaire (UEQ) and the System Usability Scale (SUS) after the third and fifth phases, with the aims to assess the user experience and the usability of the immersive platforms. The ensuing section delineates the results for each dimension, grounded in self-report outcomes displayed in Fig. 8.

TABLE II
QUESTIONNAIRE B

Campus Tour	A tour of the virtual campus sparked my interest in 3D modeling.
	Watching the modeling history of campus structures sparked my interest in 3D modeling.
Modeling Instruction	The virtual modeling instruction module helps me understand 3D modeling more easily.
	The virtual modeling instruction module helps me learn 3D modeling skills more efficiently.

5) Learning Motivation: Figure 8(i) reveals a notable disparity in learning motivation between the AR and VR platforms (χ^2=3.99, p=0.0458). AR (M=2.075) exhibited a higher average motivation score compared to VR (M=1.625). This suggests that the AR version of the Campus Tour might be more effective in engaging and motivating learners.

6) Learning Effectiveness: As illustrated in Figure 8(ii), while there was no statistically significant difference in learning effectiveness between the AR and VR platforms, AR (M=2.125) consistently scored higher on average than VR (M=1.5). This trend indicates a possible preference or suitability of AR in enhancing the comprehension and application of 3D Modeling Instruction.

7) User Experience: Figure 8(iii) indicates a significant difference in user experience between the AR and VR platforms (χ^2=4.9, p=0.0269), with AR (M=2.1063) notably outperforming VR (M=1.4375). This suggests that users found the AR interface or interaction more pleasant or intuitive, contributing to a more positive learning experience.

8) Usability: As depicted in Figure 8(iv), no significant difference was observed in the usability scores between AR and VR. However, AR (M=81.75) demonstrated a higher average usability score compared to VR (M=74). Although not statistically significant, this trend might indicate a slight preference or ease of use associated with the AR platform.

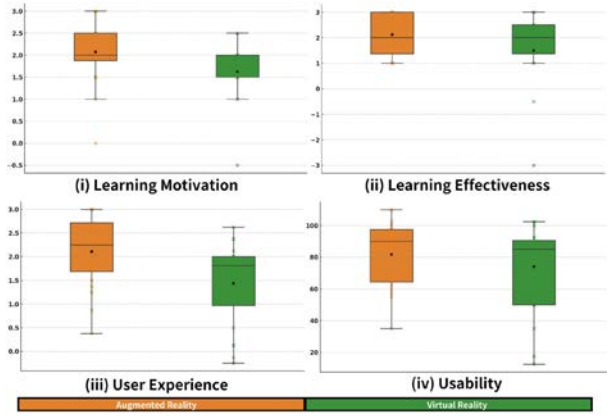


Fig. 6. Self report results of Questionnaire B, UEQ and SUS

This part of findings underscores the nuanced differences in learner engagement, effectiveness, user experience, and usability between the AR and VR platforms. While both platforms exhibit strengths, AR consistently scored higher across several metrics, suggesting it may offer a more compelling and user-friendly approach in certain contexts. These insights are invaluable for educators and developers seeking to optimize immersive technologies for enhanced educational outcomes.

In general, the analysis of self-reported outcomes across eight dimensions underscores the positive impact of immersive platforms on 3D modeling instruction. When compared to traditional teaching methods, AR and VR platforms often show superior performance, likely due to their more engaging and realistic experiences, coupled with enhanced spatial representation. Notably, AR consistently outperforms VR,

potentially owing to its integration with the real environment, fostering improved spatial imagination critical for modeling. Additionally, the portability and familiarity of handheld AR devices over HMD VR systems offer greater convenience and practicality. These results indicate that while both AR and VR are effective for modeling education, AR's unique blend of real-world context and user-friendliness makes it particularly advantageous for enhancing learning experiences in modeling education.

V. Conclusion

This study, meticulously anchored in the three main features of the proposed framework, presents a compelling approach to integrating immersive technologies into modeling instruction. Embracing an educational lens, it becomes evident that immersive technologies like AR and VR significantly enhance learners' engagement through situational learning, providing access to content and experiences that transcend the limitations of traditional educational methods. These assistive platforms, particularly beneficial for novices, offer several trifold advantages, such as fueling learning motivation, enriching the user experience, and heightening the relevance of educational content. Further, the research delves into the subjective distinctions elicited by the use of immersive platforms in contrast to conventional teaching methods. The findings illuminate that immersive platforms complement and positively augment traditional teaching approaches. Notably, the study reveals a pronounced superiority of handheld AR environments over head-mounted VR settings in terms of overall effectiveness and user preference. This is likely due to AR's seamless blending of digital and real-world elements, fostering an enriched, more accessible learning experience. Consequently, this study posits that a greater emphasis should be placed on handheld AR when developing content for modeling instruction utilizing immersive technologies. Its demonstrated effectiveness, coupled with ease of use and practical applicability, makes it an ideal choice for enhancing modern educational practices in 3D modeling. This insight is pivotal for educators and content developers, highlighting the transformative potential of AR in reshaping and advancing the landscape of educational technology.

Acknowledgments

The authors thank Yixin Liu and Yuwei Liu at Design School, Xi'an Jiaotong-Liverpool University for their support in the modelling of 3D campus structures and the design of 2D graphic fragments implemented in the immersive platforms of this study.

References

[1] H.-C. K. Lin, Y.-H. Lin, T.-H. Wang, L.-K. Su, and Y.-M. Huang, "Effects of incorporating augmented reality into a board game for high school students' learning motivation and acceptance in health education," *Sustainability*, vol. 13, no. 6, p. 3333, 2021.

[2] S. Chirankar, S. K. S. Munda, A. Das, A. Patra, E. Jami, K. Meena, S. Sonu, and S. Das, "Introducing peer-assisted learning concept in a design course," *Engineering and Product Design Education*, 2022.

[3] Y. Xu, M. Huang, W. Sun, R. Yang, M. Imparato, and H. N. Liang, "Designing an AR-based materials library for higher education: offering a four-know learning structure for design and engineering students," *9th International Conference of the Immersive Learning Research Network,* 2023.

[4] Z. Xu, M. Huang, R. Yang, L. Wang, and Y. Liu, "Development of a 3D modelling gallery based on virtual reality," *9th International Conference of the Immersive Learning Research Network*, 2023.

[5] C. Wu, M. Huang, R. Yang, W. Sun, Y. Liu, and Y. Liu, "An augmented reality platform with gamification for learning based on virtual campus scenes," *2nd IEEE International Conference on Cognitive Aspects of Virtual Reality*, 2023

[6] I. Onopriienko, K. Onopriienko, and S. Bourekkadi, "Immersive technologies in adult learning as an innovative marketing tool in the educational market," *Business Ethics and Leadership*, vol. 7, no. 2, 2023.

[7] M. Dunleavy and C. Dede, "Augmented reality teaching and learning," in *Encyclopedia of the Sciences of Learning*, 2012.

[8] P. Aiello, F. D'Elia, S. D. Tore, and M. Sibilio, "A constructivist approach to virtual reality for experiential learning," *E-Learning and Digital Media*, vol. 9, no. 3, pp. 317–324, Sep. 2012.

[9] W. Sun, M. Huang, C. Wu, R. Yang, J. Han, and Y. Yue, "Evaluating the feeling of control in virtual object translation on 2D interfaces," *Artificial Intelligence for Engineering Design, Analysis and Manufacturing,* vol. 37, e9, pp. 1–17, 2023.

[10] I. Horváth, Á. B. Csapó, B. Berki, A. Sudár, and P. Baranyi, "Definition, background and research perspectives behind 'cognitive aspects of virtual reality' (CVR)," *Infocommunications Journal*, vol. 15, pp. 9–14, 2023.

[11] M. Billinghurst and A. Dünser, "Augmented reality in the classroom," *IEEE Computer,* vol. 45, no. 7, pp. 56–63, 2012.

[12] L. Kerawalla, R. Luckin, S. Seljeflot, and A. Woolard, "'Making it real': exploring the potential of augmented reality for teaching primary school science," *Virtual Reality*, vol. 10, no. 3-4, pp. 163–174, 2006.

[13] J. Garzón and J. Acevedo, "Meta-analysis of the impact of augmented reality on students' learning gains," *Educational Research Review*, vol. 27, pp. 244–260, 2019.

[14] H. Köse and N. Güner-Yildiz, "Augmented reality (AR) as a learning material in special needs education," *Education and Information Technologies*, vol. 25, pp. 4543–4556, 2020.

[15] E. Abad-Segura, M.-D. González-Zamar, A. Luque-de la Rosa, and M. B. Morales Cevallos, "Sustainability of educational technologies: an approach to augmented reality research," *Sustainability,* vol. 12, no. 10, Art. no. 4091, 2020.

[16] M. Akçay, "Advantages and challenges associated with augmented reality for education: a systematic review of the literature," *Educational Research Review,* vol. 20, pp. 1–11, 2017.

[17] M. Bower, C. Howe, N. McCredie, A. Robinson, and D. Grover, "Augmented reality in education — cases, places, and potentials," *2013 IEEE International Conference on Computer and Information Technology*, pp. 82–89, 2013.

[18] Z. Guo, D. Zhou, J. Chen, J. Geng, C. Lv, and S. Zeng, "Using virtual reality to support the product's maintainability design: immersive maintainability verification and evaluation system," *Computers in Industry*, vol. 101, pp. 103–114, 2018.

[19] T. Setti and Á. B. Csapó, "Cognitive aspects of 2D content integration and management in 3D virtual reality spaces," *Infocommunications Journal*, vol. 15, pp. 37–45, 2023.

[20] G. Raptis, C. Fidas, and N. Avouris, "Effects of mixed-reality on players' behaviour and immersion in a cultural tourism game: a cognitive processing perspective," *International Journal of Human-Computer Studies,* vol. 114, pp. 69–79, 2018.

[21] F.-K. Chiang, X. Shang, and L. Qiao, "Augmented reality in vocational training: a systematic review of research and applications," *Computers in Human Behavior*, vol. 127, 2022.

[22] W. Wu, K. Manabe, M. W. Marek, and Y.-M. Shu, "Enhancing 21stcentury competencies via virtual reality digital content creation," *Journal of Research on Technology in Education*, vol. 53, no. 4, pp. 287–305, 2021.

[23] C. Arissen, L. van der Helm, B. Dijkstra, and W. Markus, "Virtual reality to support inpatient addiction treatment: patients are ready, what about therapists? a feasibility study," *International Journal of Mental Health and Addiction*, 2022.

[24] J. Liu, "Research on the application design of computer virtual reality technology in animation," in *2022 4th International Conference on Digital Society and Creative Animation*, 2022.

[25] A. Ghanizadeh, M. Tabeie, and Z. Pourtousi, "The role of university instructor's narrative in students' sustained attention, emotional involvement and cognitive learning," *Journal of Applied Research in Higher Education*, 2023.

[26] 24. H. Matovu, D. Ungu, M. Won, C.-C. Tsai, D. Treagust, M. Mocerino, and R. Tasker, "Immersive virtual reality for science learning: design, implementation, and evaluation," *Journal of Moral Education,* vol. 51, no. 4, pp. 490–507, 2022.

[27] H. Shen and X. Chen, "Virtual reality-based internet + smart classroom," *Journal of Information Technology*, vol. 32, no. 3, pp. 213–219, 2022.

[28] C. Wu, M. Huang, W. Sun, and R. Yang, "Feeling of control in augmented reality and virtual reality for virtual object manipulation," *9th International Conference on Virtual Reality*, pp. 193–199, 2023.

[29] L. Wang, M. Huang, R. Yang, H-N. Liang, J. Han, and Y. Sun, "Survey of movement reproduction in immersive virtual rehabilitation," *IEEE Transactions on Visualization and Computer Graphics*, vol. 29, no. 4, pp. 2184–2202.

[30] J. Zhang, M. Huang, R. Yang, Y. Wang, X. Han, J. Han, and H-N. Liang, "Understanding the effects of hand design on embodiment in virtual reality," *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, vol. 37, e10, pp. 1–14, 2023.

[31] M. M. Khosasih and D. Herumurti, "Website, AR, VR: Comparison for learning motivation," in *2021 International Conference on Information Technology Systems and Innovation (ICTS)*, 2021.

[32] V. Lara-Prieto, M. Ruiz-Cantisani, C. Mourgues, L. Pinzón-Salcedo, J. Bernal-Alvarado, and L. A. Ramírez-Robles, "Design process of extended reality educational resources in engineering: a comparison of three cases in latin american universities," in *2022 IEEE Global Engineering Education Conference (EDUCON)*, 2022.

[33] M. C. J. Lizandra and D. Pérez, "Using augmented and virtual reality for the development of acrophobic scenarios. comparison of the levels of presence and anxiety," *Computers & Graphics*, vol. 34, no. 6, pp. 756–766, 2010.

[34] J.-J. Arino, M.-C. Juan, J.-A. Gil-Gómez, and R. Mollá, "A comparative study using an autostereoscopic display with augmented and virtual reality," *Behaviour & Information Technology*, vol. 33, no. 6, pp. 646–655, 2013.

[35] G. Zari, S. Condino, F. Cutolo, and V. Ferrari, "Magic leap 1 versus microsoft hololens 2 for the visualization of 3d content obtained from radiological images," *Sensors,* vol. 23, no. 6, 2023.

[36] W. Hürst and R. Geraerts, "Augmented and virtual reality interfaces for crowd simulation software-a position statement for research on use-casedependent interaction," in *2019 IEEE Virtual Humans and Crowds for Immersive Environments (VHCIE)*, 2019.

[37] B. Karami, R. Koushki, F. Arabgol, M. Rahmani, and A. Vahabie, "Effectiveness of virtual/augmented reality-based therapeutic interventions on individuals with autism spectrum disorder: a comprehensive meta-analysis," *Frontiers in Psychiatry*, vol. 12, 2021.

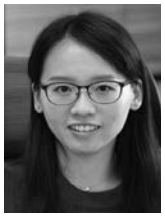
[38] P. Ravikumar, B. J. McDonald, I.-S. Shin, K. Zbeeb, and N. Puneeth, "Enhancing learning of kinematics and fatigue failure theories using cad modeler," in *Mechanical Engineering*, 2019.

[39] G. Ryan, S. Callaghan, A. R. Rafferty, M. Higgins, E. Mangina, and F. Mcauliffe, "Learning outcomes of immersive technologies in health care student education: systematic review of the literature," *JMIR Medical Education*, vol. 8, no. 1, 2022.

[40] W. Oliveira, J. Hamari, S. Joaquim, A. Toda, P. Palomino, J. Vassileva, and S. Isotani, "The effects of personalized gamification on students' flow experience, motivation, and enjoyment," *Smart Learning Environments*, vol. 9, no. 1, 2022.

[41] S. Vemula, "Leveraging VR/AR/MR and AI as innovative educational practices for 'iGeneration' students," in *Intelligent Systems for Science and Information*, 2020.

Chenxin Wu received the BEng degree in Digital Media Technology from Xi'an Jiaotong-Liverpool University, China. He is currently working as a research assistant in Xi'an Jiaotong-Liverpool University. His research interests include human-computer interaction and interactive experience.



Mengjie Huang received the PhD degree from the National University of Singapore, Singapore. She is currently an associate professor in the Design School, Xi'an Jiaotong-Liverpool University, China. Her current research interests include humancomputer interaction and human factors.

Rui Yang received the BEng degree and PhD degree from National University of Singapore, Singapore. He is currently an associate professor in the School of Advanced Technology, Xi'an Jiaotong-Liverpool University, China. His general research interest include intelligent control and optimization.

Zhaoyu Xu received the BSc degree in Information and Computing Science from Xi'an Jiaotong-Liverpool University, China. He is working toward the master degree at the Australian National University. His research interests include computer technology and virtual reality.

Wenxin Sun received the MSc degree in computer science from The Chinese University of Hong Kong, Hongkong, China. He is currently working toward the PhD at the University of Liverpool, U.K. His current research interests include immersive technology and user experience.

Liu Wang received the MEng degree in industrial design from the Beijing Institute of Technology, China. She is currently working toward the PhD at the University of Liverpool, U.K. Her research interests include human-computer interaction and embodied experience in virtual reality.

Towards Automated Musical Anamnesis for Music-based Intervention in Dementia Patients

Fabian Simmank, Katarzyna Grebosz-Haring, Thomas Ballhausen, Christian Thomay, Martin Biallas, and Markus Tauber

***Abstract*—Dementia is a neurodegenerative disease affecting millions worldwide, leading to cognitive decline and difficulties in daily activities. Music-based interventions offer a promising, cost-effective, non-pharmacological approach to improving quality of life for people with dementia. However, understanding both preferred and familiar music, as well as individual music affinity, is crucial to avoid overstimulation and ensure meaningful engagement. Developing a protocol for musical anamnesis, which gathers a patient's musical history and hearing health, demands significant manual effort and expertise, limiting its scalability. An automated approach could enhance the sustainability of musicbased therapy by reducing therapist time while maintaining relevance and preference evaluation. Here, we introduce Automated Musical Anamnesis (AMA), a personalized, scalable intervention combining interdisciplinary methods to support people with dementia.**

***Index Terms*—Terms—Dementia, P4 Medicine, Music Therapy, Digital Therapeutics, Music information retrieval**

I. Introduction

Dementia is a neurodegenerative condition that affects millions worldwide, leading to memory loss, cognitive decline, and emotional dysregulation, which significantly reduce well-being and quality of life while increasing family caregiver distress [1]. Due to the limited efficacy and potential side effects of medications, non-pharmacological, effective, scalable, and feasible interventions are now a priority. Music-based interventions have emerged as a promising, cost-effective, non-pharmacological approach for dementia patients by tapping into preserved musical memories [2], [3]. These interventions encompass various approaches, including music therapy, where licensed music therapists design programs involving active participation (e.g., instrumental play, singing) or receptive engagement (e.g., listening). Another prevalent practice involves the independent use of pre-recorded music (music listening intervention) due to its accessibility and cost-effectiveness. Music listening interventions are not only highly accepted but also easily implemented. However, studies suggest that such interventions must meet at least two prerequisites for optimal application. First, they must engage individual autobiographical musical memories, which requires knowledge of both preferred and familiar music that can elicit such memories. Second, and perhaps more importantly, an individual's affinity for music listening must be assessed to ensure that under- or overexposure to music stimulation is avoided, thereby guaranteeing high-quality listening experiences. Additionally, with age-related hearing decline and the prevalence of conditions such as tinnitus, hyperacusis, or hearing loss—along with the potential use of hearing aids—extra care must be taken to tailor music programs to the personal needs of each patient.

Developing a successful protocol for musical anamnesis, which involves gathering a patient's musical history and hearing health, demands substantial manual effort and expertise, making it challenging to ensure scalability. Traditional anamnesis methods rely on direct interviews or questionnaires [4], [5]. Consequently, there is considerable potential for improvement in this area, leveraging both therapeutic expertise and advancements in digital technology. Automating the process of musical anamnesis can facilitate the collection and analysis of vast amounts of data, incorporating personal preferences, past musical experiences, and associated memories. This can lead to a more precise and faster understanding of an individual's musical preferences, enabling tailored therapeutic interventions. Furthermore, automating the anamnesis process can enhance personalization, adapting music-based therapy to the specific needs and preferences of each dementia patient while improving accuracy by minimizing human error and bias.

Automated systems can analyze extensive musical databases and generate personalized playlists or musical interventions aligned with an individual's background and emotional connections to music. This level of personalization has the potential to strengthen therapeutic effects and increase patient engagement while improving accessibility to music-based interventions for individuals with dementia, their family caregivers, and healthcare professionals.

This paper outlines the potential of Automated Musical Anamnesis (AMA) and demonstrates how AMA can contribute to the effectiveness and sustainability of music-based adjuvant therapies for dementia. Beyond establishing this position, the paper aims to advance the field by presenting the

Fabian Simmank is with Research Studios Austria FG, Vienna, Austria, (e-mail: fabian.simmank@researchstudio.at)
Katarzyna Grebosz-Haring is with Mozarteum University Salzburg and Paris Lodron University Salzburg, Interuniversity Organisation Science & Art, Austria (e-mail: katarzyna.grebosz-haring@plus.ac.at)
Thomas Ballhausen is with Mozarteum University Salzburg, Department of Scenography, Austria (e-mail: thomas.ballhausen@moz.ac.at)
Christian Thomay is with Research Studios Austria FG, Vienna, Austria (e-mail: christian.thomay@researchstudio.at)
Martin Biallas is with Lucerne University of Applied Sciences and Arts, School of Engineering and Architecture, Switzerland (e-mail: martin.biallas@hslu.ch)
Markus Tauber is with Research Studios Austria FG, Salzburg, Austria (e-mail: markus.tauber@researchstudio.at)
Manuscript received 31.01.2024
revised Manuscript received 25.06.2024

DOI: 10.36244/ICJ.2025.6.6

state of the art in music-based interventions while proposing a novel combination of methods and tool support, detailed in subsequent sections. Within this scope, the paper contributes to the paradigm of P4 medicine (predict, prevent, personalize, and participate) by emphasizing a personalized approach in flexible environments and a data-driven foundation, potentially enabling early detection and mitigation of symptoms in the long run. The emergence of P4 medicine, which relies on advanced sensors and low-cost digital instruments to build a new healthcare ecosystem, presents a significant opportunity with vast market potential for the European electronic components and systems industry. This includes over 25,000 SME MedTech companies across Europe and forms part of the strategic research agenda of the European ECS Industry Associations [6].

Taken together, this convergence of various fields and technological approaches—coined as a new digital reality—highlights a compelling case for infocommunications [7]. The paper is structured as follows: Section II and Section III review the state of the art in musical interventions for dementia and musical anamnesis, respectively. Section IV discusses relevant psychophysiological parameters and the sensors used to measure them. Section V presents the proposed computational modeling approach. Section VI explores the tool support from a holistic user perspective. Finally, Section VII highlights the societal relevance of the solution.

II. Current Status of Musical Intervention for Dementia

Dementia encompasses various degenerative and chronically progressive brain disorders that result in memory impairments as well as behavioral and psychological disturbances, often accompanied by high comorbidity with conditions such as depression and agitation.

Previous research suggests that music-based interventions are associated with positive outcomes at both psychological and physical levels. For instance, these interventions can elicit positive emotions [8], [9], uplift mood [10], and induce both arousing and relaxing experiences [11]–[13]. Furthermore, they have been shown to alleviate stress and anxiety and are linked to reduced cortisol levels [14]–[16]. These findings have inspired the development of practical treatment programs for adjuvant therapy targeting a broader spectrum of psychosomatic conditions and neurodegenerative illnesses [17].

The field of neurocognition provides valuable insights into musical processing and its emotional effects, which often involve activation changes in the brain's core emotion-processing structures. These findings form a crucial basis for understanding cerebral music processing and its potential clinical applications, particularly for patients with neurodegenerative disorders [17]–[19]. Although no research has specifically addressed dementia patients' assessment of digital media performance quality, relevant insights emerge from a community project involving adolescents undergoing psychiatric treatment: In this project, Mozart's works were arranged innovatively with multimedia support from a collective of artists. The intervention demonstrated individual benefits of the arts for these adolescents, including reduced psychopathological symptoms, improved self-esteem, and better emotional and behavioral regulation, including media consumption habits [20].*

Regarding dementia, music-based interventions show beneficial outcomes across various domains (see Fig. 1 for a summarizing overview). Listening to individualized, personally relevant music is particularly promising for dementia patients, as it can elicit emotional responses and tap into autobiographical memories tied to life experiences [2], [21], [22]. Studies indicate that familiar receptive music, when combined with cognitive training or physical exercise, improves overall cognitive performance compared to standard treatments. Notable improvements have been observed in attention, executive functions, orientation, verbal memory, and episodic memory. Additionally, these interventions have shown positive effects on mood, reducing symptoms of agitation, anxiety, and depression [2], [23].

However, the type of dementia may influence therapeutic responses. For example, patients with frontotemporal degenerative dementia often struggle more with emotional associations in music than those with Alzheimer's disease. This suggests that the effectiveness of interventions may vary based on the specific type of dementia. It is hypothesized that cognitive and emotional gains from music-based interventions may stem from either music-induced dopamine release and activation of the brain's reward system or stimulation of the parasympathetic nervous system [2]. Nevertheless, the causal relationship between music-induced mood improvements and underlying neurological changes remains unclear.

Imaging studies provide insights into the neurophysiological mechanisms behind musical interventions in dementia [17]. For example, research has shown that familiar music activates the medial prefrontal cortex in healthy individuals, and this brain region degenerates more slowly in Alzheimer's disease. This slower degeneration may explain why patients with Alzheimer's can recognize familiar songs and retrieve personally significant episodic memories even in the later stages of the disease [21], [24]–[26]. Additionally, King et al. [27] using functional magnetic resonance imaging (fMRI), demonstrated that listening to preferred music excerpts activates the supplementary motor area, a region associated with memory for familiar music and less affected in the early stages of Alzheimer's. They also noted increased activity in the cerebral cortex and cerebellum, which are associated with sensory and attention-related functions.

In summary, existing evidence supports receptive music as a positive factor in the treatment of dementia. However, the development of a standardized protocol for musical anamnesis

*"How to Find Myself Through Mozart": A project by Katarzyna Grebosz-Haring and Belinda Plattner in cooperation with the inter-university institution "Wissenschaft & Kunst" of the Paris Lodron University Salzburg and the University Mozarteum Salzburg, as well as the University Clinic for Child and Adolescent Psychiatry of the Paracelsus Medical Private University and the art collective "gold extra"

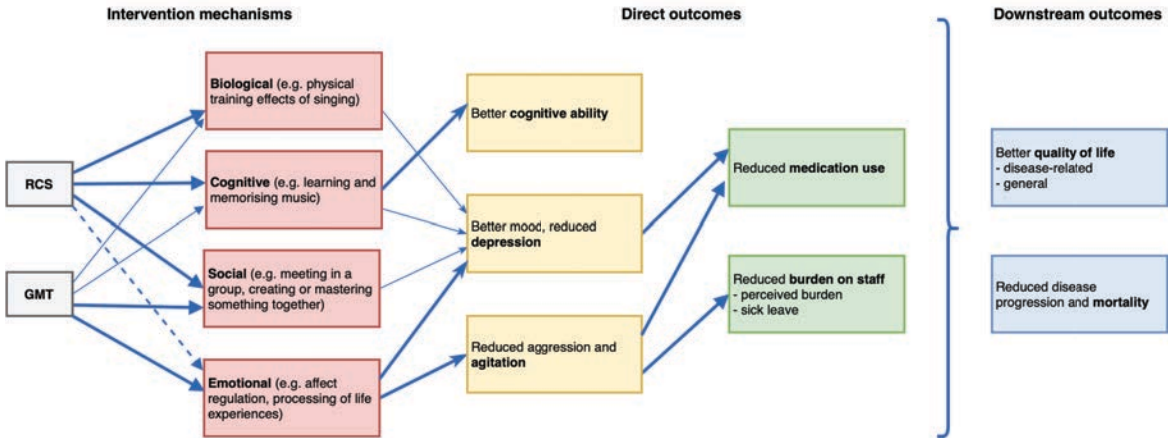


Fig. 1: Mechanisms and processes of music interventions in dementia patients. RCS: Recreational choir singing, GMT: Group music therapy

remains essential to ensure the effectiveness and scalability of these interventions.

III. Anamnesis as a process: State of the art

Anamnesis in music-based interventions aims to gather information about a patient's individual music preferences, performing history, and habits. By understanding these preferences, an appropriate selection of music and environmental factors can be prepared for subsequent music listening sessions. Typically, anamnesis is conducted through interviews and questionnaires, either via telephone or face-to-face, to identify personally relevant music for each individual. This information may be collected from family members, nursing staff, or directly from participants, provided they can articulate their preferences. Additionally, short clips of musical selections—representing genres, artists, or songs suggested in the questionnaire—may be played to the individuals. Patients are then observed for behavioral indicators such as straightening of posture, increased alertness, engagement, smiling, or moving to the rhythm of the music [28]–[30]. Relevant information includes favorite songs and artists, preferred musical genres and styles, and favored musical epochs. For patients with dementia, the primary focus is on music activation programs rather than the conventional quality of musical performance. This approach often requires extensive effort and may necessitate multiple sessions. When patients are unable to express their preferences or emotional associations verbally, trained therapists must rely on non-verbal behavior and body signals to draw conclusions. It is evident that achieving success in this area demands substantial individualized counseling time. Depending on the communicative abilities of the patient, information from proxies such as relatives or caregivers should also be considered in constructing appropriate playlists. In cases where such information is unavailable, research on autobiographical musical memory can help identify music that the patient might recognize or respond to. The advent of music streaming services has further facilitated this process, enabling immediate access to and selection of music without logistical challenges.

IV. Making use of methods: Psycho-Physiology and Sensorics

As outlined above, there is extensive evidence supporting the use of music-based interventions as adjuvant therapy. The integration of digital information technology introduces the potential for scaling these interventions, enabling broader accessibility to larger target groups in less time. Consequently, the upcoming sections present a tool support framework for AMA, detailing methods and technologies from various domains. This approach leverages cognitive abilities and digital tools to augment or substitute lost capabilities. It integrates technological and psychological expertise, along with specific requirements, as a prerequisite for clinical trials. This entails a psycho-physiological approach to measure cognitive and emotional states, translating these into parameters used to describe retrievable features of music. The methods it builds on and components required will be described in the following. The automated interpretation of cognitive capabilities requires the sensor-based assessment of associated somatic and behavioral expressions, comprising psycho-physiological and behavioral indicators: Psycho-physiological indicators, such as heart rate variability (HRV), skin conductance, and blood pressure, etc., correlate with attentional mechanisms and emotions, providing insights into arousal and valence [31], [32]. These measures exploit the body's physical reactions during or in response to cognitive activities, offering continuous data for noninvasive and noninterruptive analysis of user-stimulus interactions. However, certain psycho-physiological measures face limitations, such as high obtrusiveness (e.g., muscular tension [33], blood sugar [34]), insufficient temporal resolution (e.g., galvanic skin response [35], [36]), or poor transferability between individuals (e.g., ECG, HRV [37]). Among these, pupil dilation emerges as the most promising indicator of cognitive states [38]–[40]. Behavioral expressions

of cognitive capabilities involve observable activities related to (i) information perception, such as visual attention, gaze behavior (e.g., saccadic eye movements, fixations [41], [42], head movements [42], [43]), and (ii) descriptive qualities of task and movement execution, such as steadiness and coordination of hand movements [44], [45]. The envisioned digitization of AMA focuses on analyzing and interpreting observable changes in overt behavior during music listening. Overt behavior includes body movements or posture changes observable by others, which may indicate relaxation versus tension, positive versus negative emotion, or engagement with the music (e.g., rhythmic tapping of hands, feet, or fingers). Metrics like gaze behavior and cognitive load can further assess attention and cognitive activation during music perception [28], [46]–[48].

To achieve this, relevant behaviors can be measured using various sensors, including optical sensors (e.g., cameras with skeleton tracking), body-worn sensors (e.g., accelerometers for activity recognition), and remote or head-worn eye trackers. The trade-off between sensor proximity and invasiveness influences patient acceptance and compliance. Body-worn sensors offer high data quality and immersive somatic experiences but may face low acceptance due to their invasive application and complexity, limiting scalability. Conversely, remote sensing approaches, such as camera-based systems and remote eye trackers, offer better scalability and less obtrusiveness but at the cost of reduced data quality.

A low-level remote sensing setup, such as remote eye tracking or movement detection, can serve as a starting point. Mixed or virtual reality (XR) technologies offer a promising avenue by unifying applications and digital environments [49], [50]. A harmonized XR application—such as a headset with integrated eye tracking, visual input, and interaction devices—provides an immersive environment that enhances user experience while minimizing tedious setups. Built-in sensors within XR devices are pre-calibrated, reducing the need for aligning disparate systems. Virtual reality (VR) in particular allows to aim for a broader range of positive effects when implemented effectively [51]–[54]. Successful use cases have proven the applicability of VR in medical settings [55] as well as in education [56], [57], and professional settings [58]. Thus, a target-oriented development approach, prioritizing acceptance and compliance, is essential for obtaining valid and reliable results. The use of XR headsets offers significant advantages for initial data collection due to their advanced sensor capabilities, such as integrated eye tracking and immersive engagement. However, their size and discomfort during prolonged use present challenges for patient acceptance. To address this, we propose utilizing XR headsets exclusively in the initial stage to establish a reliable baseline of cognitive and physiological responses to musical stimuli. Following the baseline assessment (and based on the patient's preferences), the process may transition to less intrusive technologies, such as remote sensors or wearable devices, for subsequent sessions.

Based on current research and available measurements, an evaluation design for AMA development should consider the following requirements: a) Intervention type: receptive interventions b) Focus of the studies: identification of behavioral and somatic reactions to presented music c) Therapy Approach: individual listening d) Intervention setting: at nursing institutions / doctor setups e) Evaluation scale: quantification of behavioral and physiological reaction to music f) Experiment design: 3 stage process for iterative refinement of music preference model.

V. Novel Combination: Computational Modeling of Musical Preference

Understanding the factors that influence individual music preferences has been widely studied over the past decade, identifying variables such as age [59], [60], gender [61], [62], cognitive style [12], and personality [60], [63]. Recent approaches to modeling user music preferences have evolved from correlating personality traits with genres or styles to leveraging finer-grained content-level features derived from the audio itself [64]. AMA builds on these advancements by employing convolutional neural networks (CNNs) to extract high-level features from intermediate network layers [65]. AI-driven models will be utilized to interpret and quantify behavioral changes on a numerical scale from 0 to 100. This process involves the multi-dimensional mapping of behavioral descriptions onto a one-dimensional score. To achieve this, AMA integrates methods from behavioral and physiological interpretation of human attention, creating supervised machine learning models for classification tasks based on multi-modal input vectors. The interpretation of reactions to music samples will be combined with music similarity models from the literature to iteratively refine sample selection for study execution. This iterative process leverages network analysis of graph representations to identify which music samples provide the most significant insights into an individual's music preference model, thereby continuously improving the computational representation of musical taste. Beyond model architecture, the approach offers flexibility for integrating elements of interaction and more complex intervention designs. For instance, the acceptance of music supporting a particular mood may vary based on an individual's current state. In a calm state, an individual may prefer calm music to maintain that state, or they may seek more arousing and activating music. The proposed approach relies on robust cognitive measures, such as attention and overt reactions, while acknowledging that more complex interrelationships and interactions with music should be explored in future iterations. These advancements extend beyond the scope of traditional anamnesis and will require further refinement.

Fig. 2 shows a design of a tool support system built by the authors to prepare such an interacting environment. It contains an XR device enabling the users to interact in a game-like setting in order to trigger emotion- and/or cognition-based reactions that can be used to gain insights into the user's emotional and cognitive states while performing a task and listening to music. Psycho-physiological measures such as built-in eyetracking as well as heart rate measurement are

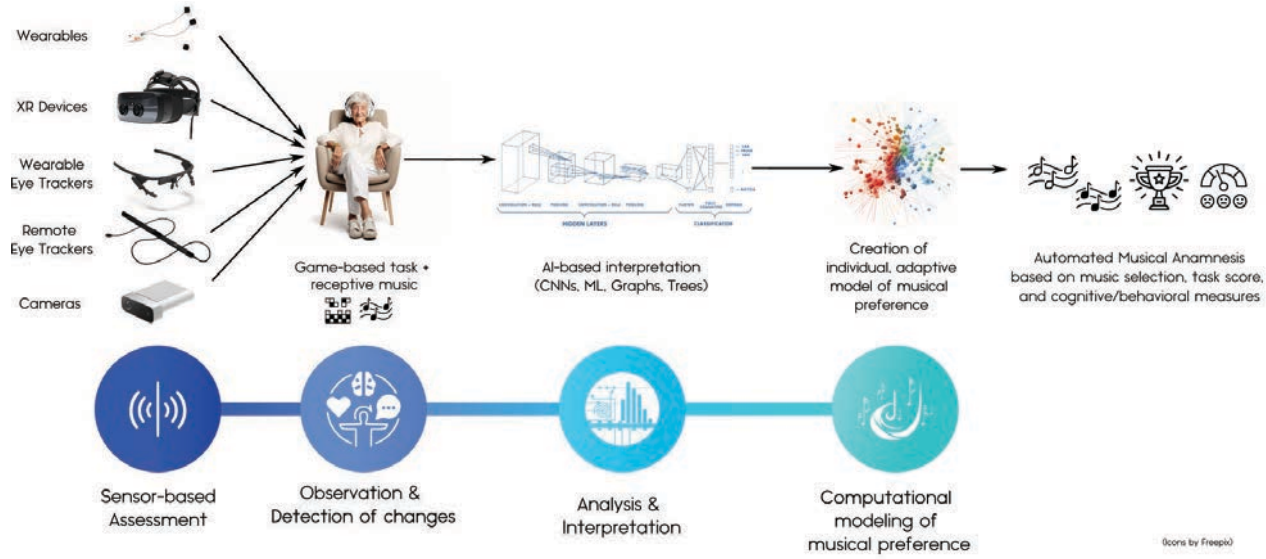


Fig. 2: Conceptual design of a tool support solution developed to conduct pilot studies for model development. A prototype was created around a reaction game with increasing difficulty built with Unity engine, a Varjo XR3 headset with eyetracking capabilites, and a self-developed protocol for structured data collection and preprocessing.

taken into account. The tool support is able to play different kinds of music to the user and analyze acquired data separately. Results will be processed into the music recommender being under development. As such, the demonstrator will be used to conduct experimental pilot studies preceding clinical studies and thereby enable the researchers to create the model described above. Further details of the setup with regard to the user-centered approach applied are described in the following section.

VI. Holistic Tool Support: Integrating User-Centered Design, Methodologies, and Ethical Considerations

In a broader context, the overarching goal of an AMA system is to become a widely adopted tool in care settings. Achieving this objective necessitates the application of various methodologies and best practices. A user-centered design (UCD) approach is particularly suitable, as it involves a structured process that incorporates input from target group individuals throughout all phases of system development, including defining the context of use, establishing requirements, designing solutions, and conducting evaluations. Best practices emphasize the inclusion of all relevant stakeholders [66], [67]. Depending on the deployment environment, different stakeholder groups must be considered. While patients with dementia and music therapists are the primary users, informal caregivers (e.g., family members) and professional caregivers must also play integral roles. In nursing home settings, additional representation from staff, such as care managers and facility management (covering IT infrastructure, care documentation, and billing), should be included in the UCD process. Complementing the UCD approach with methods specifically designed for individuals with dementia is crucial to ensuring user acceptance, addressing ethical considerations, and creating solutions for patients across all stages of the condition. Tailored methods are particularly necessary for individuals with advanced dementia. The importance of the care dyad—comprising the patient with dementia and their caregiver—is emphasized in individualized care settings [68], [69]. Principles of "compassionate design" for cognitively impaired individuals, as proposed by [70], can also be applied to an AMA system. These principles advocate for designs that stimulate the senses, are highly personalized, and foster connections between people.

Methods for analyzing the acceptance of technological solutions are well-established and applicable to the development of an AMA system. The Technology Acceptance Model (TAM), which focuses on perceived usefulness and ease of use [71], and the Unified Theory of Acceptance and Use of Technology (UTAUT), which considers performance expectancy, effort expectancy, social influence, and facilitating conditions [72], are particularly relevant. While alternative technology acceptance models exist, TAM and UTAUT are widely used in healthcare [73] and are well-suited for optimizing system development. While newly developed solutions for people with dementia have the potential to enhance quality of life, it is imperative to ensure they do not compromise privacy, freedom, or human rights [74]. Consequently, the development of an AMA system will incorporate the ethical adoption model proposed by [75], which is based on five pillars: inclusive participatory design, emotional alignment, adoption modeling, ethical standards assessment, and education and training. The publication offers 18 recommendations derived from this model.

P4 medicine (predict, prevent, personalize, and participate) provides an overarching framework that encompasses all relevant objectives for developing holistic solutions in digital health and therapeutics. By emphasizing prevention and home care, P4 medicine aligns with the needs of patients suffering from chronic conditions while supporting aging well and value-based healthcare. These principles, as outlined in the Strategic Research and Innovation Agenda of the European Commission [6], form a robust foundation for all user-centered and ethical considerations in the development of the AMA system.

VII. Conclusion and Final Remarks

Dementia presents a fundamental challenge to society as a whole and to each affected individual. Musical treatment approaches are among the few interventions capable of successfully activating cognitive, behavioral, and emotional resources in dementia patients, even in late stages, thereby enhancing well-being and quality of life. Significant progress has been made in understanding both the neurodegenerative effects of dementia and the potential of mitigating therapies.

However, music-based interventions face scalability challenges due to the extensive manual effort required for musical anamnesis. From a societal perspective, the urgency to develop scalable therapeutic approaches is heightened by the expected global increase in dementia cases. The development of automated processes to facilitate and objectify musical anamnesis holds the potential to deliver substantial societal impact by providing effective treatments to a broader patient population.

This paper has presented the state-of-the-art research and processes in music therapy, with a particular focus on musical anamnesis. It has explored how dementia affects cognitive and emotional capabilities, the existing interventions, and the potential benefits of these approaches. By introducing a range of methods and technological solutions, the paper outlines all necessary components for building an automated musical anamnesis tool support system. Developing an AMA solution addresses a highly interdisciplinary challenge, requiring the integration and combination of diverse methodologies. In this context, a content-driven approach necessitates a deep understanding of music and its associated contexts, while also addressing issues of inclusion, care, and sustainability. The availability of cultural content in a free and structured manner is a crucial factor, emphasizing the importance of carefully curated digitized artifacts enriched with metadata, narrativity, and interconnectedness. These elements enable the meaningful use of repositories and foster the use of both digitized and digital-born cultural heritage. For this endeavor to succeed, culture must be positioned at the core of all development steps and processes, ensuring that technological advancements go beyond functioning merely as tools for distribution or commercialization. We therefore aim at a renewed understanding of culture tech to ensure an intertwinedness of culture and technology that transcends the concept of a mere toolbox to help distribute or market content. That also includes a broader and more informed understanding of cultural heritage that is not only material for the worst-case stress test of technological developments, but rather at the core of all described endeavours [76].

Music intervention is an efficient, cost-effective, and easily applicable rehabilitation strategy for treating dementia. The proposed approach seeks to automate the labor-intensive process of musical anamnesis and content selection, enabling scalable applications and amplifying the impact of musical interventions in dementia care. It will build upon cognitive, behavioral and physiological indicators to identify interaction with presented music to automatically build models of musical preference of subjects. This innovation addresses the primary limitation of musical intervention in dementia—human effort—by providing a scalable solution that broadens accessibility and effectiveness.

References

[1] G. Livingston, A. Sommerlad, V. Orgeta, S. G. Costafreda, J. Huntley, D. Ames, C. Ballard, S. Banerjee, A. Burns, J. Cohen-Mansfield et al., "Dementia prevention, intervention, and care," *The Lancet*, vol. 390, no. 10113, pp. 2673–2734, 2017. [Online]. Available: DOI: 10.1016/S0140-6736(17)31363-6

[2] A. J. Sihvonen, T. Särkämö, V. Leo, M. Tervaniemi, E. Altenmüller, and S. Soinila, "Music-based interventions in neurological rehabilitation," *The Lancet Neurology*, vol. 16, no. 8, pp. 648–660, 2017. [Online]. Available: DOI: 10.1016/S1474-4422(17)30168-0

[3] J. T. Van der Steen, H. J. Smaling, J. C. Van der Wouden, M. S. Bruinsma, R. J. Scholten, and A. C. Vink, "Musicbased therapeutic interventions for people with dementia," *Cochrane Database of Systematic Reviews*, no. 7, 2018. [Online]. Available: DOI: 10.1002/14651858.CD003477.pub4

[4] L. A. Gerdner, "Individualized music for dementia: Evolution and application of evidence-based protocol," *World journal of Psychiatry*, vol. 2, no. 2, p. 26, 2012. [Online]. Available: DOI: 10.5498/wjp.v2.i2.26

[5] D. P. Schoenfelder and L. Gerdner, "Evidence-based guideline. individualized music for elders with dementia," *Journal of Gerontological Nursing*, vol. 36, no. 6, pp. 7–15, 2010.

[6] E. Commission, D.-G. for Research, and Innovation, *Strategic Research and Innovation Agenda (SRIA) of the European Open Science Cloud (EOSC)*. Publications Office of the European Union, 2022. [Online]. Available: DOI: 10.2777/935288

[7] P. Baranyi, "Special issue on internet of digital and cognitive reality: Applications and key challenges," *Infocommunications Journal*, 2023.

[8] K. Kallinen and N. Ravaja, "Emotion perceived and emotion felt: Same and different," *Musicae Scientiae*, vol. 10, no. 2, pp. 191–213, 2006. [Online]. Available: DOI: 10.1177/102986490601000203

[9] V. N. Salimpoor, M. Benovoy, G. Longo, J. R. Cooperstock, and R. J. Zatorre, "The rewarding aspects of music listening are related to degree of emotional arousal," *PloS one*, vol. 4, no. 10, p. e7487, 2009. [Online]. Available: DOI: 10.1371/journal.pone.0007487

[10] J. Völker, "Personalising music for more effective mood induction: Exploring activation, underlying mechanisms, emotional intelligence, and motives in mood regulation," *Musicae Scientiae*, vol. 25, no. 4, pp. 380–398, 2021. [Online]. Available: DOI: 10.1177/1029864919876315

[11] L. Bernardi, C. Porta, and P. Sleight, "Cardiovascular, cerebrovascular, and respiratory changes induced by different types of music in musicians and non-musicians: the importance of silence," *Heart*, vol. 92, no. 4, pp. 445–452, 2006. [Online]. Available: DOI: 10.1136/hrt.2005.064600

[12] D. M. Greenberg, S. Baron-Cohen, D. J. Stillwell, M. Kosinski, and P. J. Rentfrow, "Musical preferences are linked to cognitive styles," *PloS one*, vol. 10, no. 7, p. e0131151, 2015. [Online]. Available: DOI: 10.1371/journal.pone.0131151

[13] J. Panksepp and G. Bernatzky, "Emotional sounds and the brain: the neuro-affective foundations of musical appreciation," *Behavioural Processes*, vol. 60, no. 2, pp. 133–155, 2002. [Online]. Available: DOI: 10.1016/S0376-6357(02)00080-3

[14] A. Dell'Anna, M. Leman, and A. Berti, "Musical interaction reveals music as embodied language," *Frontiers in Neuroscience*, vol. 15, p. 667838, 2021. [Online]. Available: DOI: 10.3389/fnins.2021.667838

[15] H. Fukui and M. Yamashita, "The effects of music and visual stress on testosterone and cortisol in men and women." *Neuro Endocrinology Letters*, vol. 24, no. 3-4, pp. 173–180, 2003.

[16] G. Kreutz, C. Q. Murcia, and S. Bongard, "Psychoneuroendocrine research on music and health: an overview," *Music, Health, and Wellbeing*, pp. 457–476, 2012. [Online]. Available: DOI: 10.1093/acprof:oso/9780199586974.003.0030

[17] K. Grebosz-Haring, G. Bernatzky, F. Wendtner, and G. Kreutz, "Musikhören bei Depression und Demenz: Von der Hirnforschung zur klinischen Anwendung," *Musik und Medizin: Chancen für Therapie, Prävention und Bildung. 2nd Edition.*, in press.

[18] S. Garrido, C. J. Stevens, E. Chang, L. Dunne, and J. Perz, "Music and dementia: individual differences in response to personalized playlists," *Journal of Alzheimer's Disease*, vol. 64, no. 3, pp. 933–941, 2018. [Online]. Available: DOI: 10.3233/JAD-180084

[19] M. C. Hillebrand, L. Weise, and G. Wilz, "Immediate effects of individualized music listening on behavioral and psychological symptoms of dementia: A randomized controlled trial," *International Journal of Geriatric Psychiatry*, vol. 38, no. 3, p. e5893, 2023.

[20] F. Wallner, M. Karner, and T. Ballhausen, Eds., *Spot On MozART. Visualizing Music in the Digital Age*. Wien: Verlag für moderne Kunst, 2023.

[21] M. El Haj, L. Fasotti, and P. Allain, "The involuntary nature of musicevoked autobiographical memories in alzheimer's disease," *Consciousness and cognition*, vol. 21, no. 1, pp. 238–246, 2012.

[22] E. M. Long, "An innovative approach to managing behavioral and psychological dementia," *The Journal for Nurse Practitioners*, vol. 13, no. 7, pp. 475–481, 2017. [Online]. Available: DOI: 10.1016/j.nurpra.2017.05.003

[23] M. A. Gaviola, K. J. Inder, S. Dilworth, E. G. Holliday, and I. Higgins, "Impact of individualised music listening intervention on persons with dementia: A systematic review of randomised controlled trials," *Australasian journal on ageing*, vol. 39, no. 1, pp. 10–20, 2020. [Online]. Available: DOI: 10.1111/ajag.12642

[24] S. Eschrich, T. F. Münte, and E. O. Altenmüller, "Unforgettable film music: the role of emotion in episodic long-term memory for music," *BMC neuroscience*, vol. 9, no. 1, pp. 1–7, 2008. [Online]. Available: DOI: 10.1186/1471-2202-9-48

[25] P. Janata, "The neural architecture of music-evoked autobiographical memories," *Cerebral Cortex*, vol. 19, no. 11, pp. 2579–2594, 2009. [Online]. Available: DOI: 10.1093/cercor/bhp008

[26] C. Moreno-Morales, R. Calero, P. Moreno-Morales, and C. Pintado, "Music therapy in the treatment of dementia: A systematic review and meta-analysis," *Frontiers in medicine*, vol. 7, p. 160, 2020. [Online]. Available: DOI: 10.3389/fmed.2020.00160

[27] J. King, K. Jones, E. Goldberg, M. Rollins, K. MacNamee, C. Moffit, S. Naidu, M. Ferguson, E. Garcia-Leavitt, J. Amaro et al., "Increased functional connectivity after listening to favored music in adults with alzheimer dementia," *The journal of prevention of Alzheimer's disease*, vol. 6, pp. 56–62, 2019. [Online]. Available: DOI: 10.14283/jpad.2018.19

[28] T. T. Lineweaver, T. R. Bergeson, K. Ladd, H. Johnson, D. Braid, M. Ott, D. P. Hay, J. Plewes, M. Hinds, M. L. LaPradd et al., "The effects of individualized music listening on affective, behavioral, cognitive, and sundowning symptoms of dementia in long-term care residents," *Journal of aging and health*, vol. 34, no. 1, pp. 130–143, 2022. [Online]. Available: DOI: 10.1177/08982643211033407

[29] L. Gerdner, "An individualized music intervention for agitation," *Journal of the American Psychiatric Nurses Association*, vol. 3, no. 6, pp. 177–184, 1997. [Online]. Available: DOI: 10.1177/107839039700300603

[30] L. A. Gerdner, "Effects of individualized versus classical "relaxation" music on the frequency of agitation in elderly persons with alzheimer's disease and related disorders," *International Psychogeriatrics*, vol. 12, no. 1, pp. 49–65, 2000.

[31] S. Gabay, Y. Pertzov, and A. Henik, "Orienting of attention, pupil size, and the norepinephrine system," *Attention, Perception, & Psychophysics*, vol. 73, pp. 123–129, 2011. [Online]. Available: DOI: 10.3758/s13414-010-0015-4

[32] B. Gollan, B. Wally, and A. Ferscha, "Automatic human attention estimation in an interactive system based on behavior analysis," in *Proceedings of the 15th Portuguese Conference on Artificial Intelligence (EPIA 2011)*, 2011, pp. 40–54.

[33] B. H. Cohen, R. J. Davidson, J. A. Senulis, C. D. Saron, and D. R. Weisman, "Muscle tension patterns during auditory attention," *Biological psychology*, vol. 33, no. 2-3, pp. 133–156, 1992. [Online]. Available: DOI: 10.1016/0301-0511(92)90028-S

[34] S. H. Fairclough and K. Houston, "A metabolic measure of mental effort," *Biological psychology*, vol. 66, no. 2, pp. 177–190, 2004. [Online]. Available: DOI: 10.1016/j.biopsycho.2003.10.001

[35] J. M. Kivikangas, G. Chanel, B. Cowley, I. Ekman, M. Salminen, S. J¨arvel¨a, and N. Ravaja, "A review of the use of psychophysiological methods in game research," *Journal of Gaming & Virtual Worlds*, vol. 3, no. 3, pp. 181–199, 2011. [Online]. Available: DOI: 10.1386/jgvw.3.3.181_1

[36] C. L. Bethel, K. Salomon, R. R. Murphy, and J. L. Burke, "Survey of psychophysiology measurements applied to human-robot interaction," in *RO-MAN 2007-The 16th IEEE International Symposium on Robot and Human Interactive Communication*. IEEE, 2007, pp. 732–737. [Online]. Available: DOI: 10.1109/ROMAN.2007.4415182

[37] P. Nickel and F. Nachreiner, "Psychometric properties of the 0.1 hz component of hrv as an indicator of mental strain," in *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 44, no. 12. SAGE Publications Sage CA: Los Angeles, CA, 2000, pp. 2–747. Online]. Available: DOI: 10.1177/154193120004401284

[38] B. Gollan and A. Ferscha, "Modeling pupil dilation as online input for estimation of cognitive load in non-laboratory attention-aware systems," *COGNITIVE 2016: The Eighth International Conference on Advanced Cognitive Technologies and Applications*, 2016.

[39] O. E. Kang, K. E. Huffer, and T. P. Wheatley, "Pupil dilation dynamics track attention to high-level information," *PloS one*, vol. 9, no. 8, p. e102463, 2014. [Online]. Available: DOI: 10.1371/journal.pone.0102463

[40] J. Beatty, "Task-evoked pupillary responses, processing load, and the structure of processing resources." *Psychological bulletin*, vol. 91, no. 2, p. 276, 1982. [Online]. Available: DOI: 10.1037/0033-2909.91.2.276

[41] S. P. Liversedge and J. M. Findlay, "Saccadic eye movements and cognition," *Trends in cognitive sciences*, vol. 4, no. 1, pp. 6–14, 2000. [Online]. Available: DOI: 10.1016/S1364-6613(99)01418-7

[42] J. E. Hoffman and B. Subramaniam, "The role of visual attention in saccadic eye movements," *Perception & psychophysics*, vol. 57, no. 6, pp. 787–795, 1995. [Online]. Available: DOI: 10.3758/BF03206794

[43] E. I. Knudsen, "Fundamental components of attention," *Annu.Rev. Neurosci.*, vol. 30, pp. 57–78, 2007. [Online]. Available: DOI: 10.1146/annurev.neuro.30.051606.094256

[44] W. Zhang, L.-F. Low, M. Schwenk, N. Mills, J. D. Gwynn, and L. Clemson, "Review of gait, cognition, and fall risks with implications for fall prevention in older adults with dementia," *Dementia and geriatric cognitive disorders*, vol. 48, no. 1-2, pp. 17–29, 2019. [Online]. Available: DOI: 10.1159/000504340

[45] E. Scherder, W. Dekker, and L. Eggermont, "Higher-level hand motor function in aging and (preclinical) dementia: its relationship with (instrumental) activities of daily life–a mini-review," *Gerontology*, vol. 54, no. 6, pp. 333–341, 2008. [Online]. Available: DOI: 10.1159/000168203

[46] M. Stolte, B. Gollan, and U. Ansorge, "Tracking visual search demands and memory load through pupil dilation," *Journal of Vision*, vol. 20, no. 6, pp. 21–21, 2020. [Online]. Available: DOI: 10.1167/jov.20.6.21

[47] J. Sweller, "Cognitive load during problem solving: Effects on learning," *Cognitive Science*, vol. 12, no. 2, pp. 257–285, 1988. [Online]. Available: DOI: 10.1207/s15516709cog1202_4

[48] M. Pomplun and S. Sunkara, "Pupil dilation as an indicator of cognitive workload in human-computer interaction," in *Human-Centered Computing*. CRC Press, 2019, pp. 542–546.

[49] A. Hamad and B. Jia, "How virtual reality technology has changed our lives: An overview of the current and potential applications and limitations," *International Journal of Environmental Research and Public Health*, vol. 19, no. 18, p. 11 278, 2022. [Online]. Available: DOI: 10.3390/ijerph191811278

[50] M. Slater and M. V. Sanchez-Vives, "Enhancing our lives with immersive virtual reality," *Frontiers in Robotics and AI*, vol. 3, p. 74, 2016. [Online]. Available: DOI: 10.3389/frobt.2016.00074

[51] M. C. Howard and M. B. Gutworth, "A meta-analysis of virtual reality training programs for social skill development," *Computers & Education*, p. 103 707, 2020. [Online]. Available: DOI: 10.1016/j.compedu.2019.103707

[52] T. Tursø-Finnich, R. O. Jensen, L. X. Jensen, L. Konge, and E. Thinggaard, "Virtual reality head-mounted displays in medical education—a systematic review," *Simulation in Healthcare*, 2022.

[53] G. S. Ruthenbeck and K. J. Reynolds, "Virtual reality for medical training: the state-of-the-art," *Journal of Simulation*, vol. 9, pp. 16–26, 2015. [Online]. Available: DOI: 10.1057/jos.2014.14

[54] I. Horváth, Á. B. Csapó, B. Berki, A. Sudár, and P. Baranyi, "Definition, background and research perspectives behind 'cognitive aspects of virtual reality'(cVR)," *Infocommunications Journal*, no. SP, pp. 9–14, 2023.

[55] L. Li, F. Yu, D. Shi, J. Shi, Z. Tian, J. Yang, X. Wang, and Q. Jiang, "Application of virtual reality technology in clinical medicine," *American Journal of Translational Research*, vol. 9, no. 9, p. 3867, 2017.

[56] Y.-L. Chen, "The effects of virtual reality learning environment on student cognitive and linguistic development," *The Asia-Pacific Education Researcher*, vol. 25, pp. 637–646, 2016. [Online]. Available: DOI: 10.1007/s40299-016-0293-2

[57] L. Jensen and F. Konradsen, "A review of the use of virtual reality head-mounted displays in education and training," *Education and Information Technologies*, vol. 23, pp. 1515–1529, 2018. [Online]. Available: DOI: 10.1007/s10639-017-9676-0

[58] C. H. Wijkmark, I. Heldal, and M. M. Metallinou, "Virtual reality support of cognitive processes in firefighter skills training," in *2022 1st IEEE International Conference on Cognitive Aspects of Virtual Reality (CVR)*. IEEE, 2022, pp. 000 027–000 034. [Online]. Available: DOI: 10.1109/CVR55417.2022.9967649

[59] A. Bonneville-Roussy, P. J. Rentfrow, M. K. Xu, and J. Potter, "Music through the ages: Trends in musical engagement and preferences from adolescence through middle adulthood." *Journal of Personality and Social Psychology*, vol. 105, no. 4, p. 703, 2013. [Online]. Available: DOI: 10.1037/a0033770

[60] B. Ferwerda, M. Tkalcic, and M. Schedl, "Personality traits and music genre preferences: how music taste varies over age groups," in *1st Workshop on Temporal Reasoning in Recommender Systems (RecTemp) at the 11th ACM Conference on Recommender Systems, Como, August 31, 2017*., vol. 1922. CEUR-WS, 2017, pp. 16–20.

[61] D. M. Greenberg, M. Kosinski, D. J. Stillwell, B. L. Monteiro, D. J. Levitin, and P. J. Rentfrow, "The song is you: Preferences for musical attribute dimensions reflect personality," *Social Psychological and Personality Science*, vol. 7, no. 6, pp. 597–605, 2016. [Online]. Available: DOI: 10.1177/1948550616641473

[62] W. McCown, R. Keiser, S. Mulhearn, and D. Williamson, "The role of personality and gender in preference for exaggerated bass in music," *Personality and individual differences*, vol. 23, no. 4, pp. 543–547, 1997. [Online]. Available: DOI: 10.1016/S0191-8869(97)00085-8

[63] T. Schäfer and C. Mehlhorn, "Can personality traits predict musical style preferences? A meta-analysis," *Personality and Individual Differences*, vol. 116, pp. 265–273, 2017. [Online]. Available: DOI: 10.1016/j.paid.2017.04.061

[64] A. B. Melchiorre and M. Schedl, "Personality correlates of music audio preferences for modelling music listeners," in *Proceedings of the 28th ACM conference on user modeling, adaptation and personalization*, 2020, pp. 313–317. [Online]. Available: DOI: 10.1145/3340631.3394874

[65] M. Sheikh Fathollahi and F. Razzazi, "Music similarity measurement and recommendation system using convolutional neural networks," *International Journal of Multimedia Information Retrieval*, vol. 10, pp. 43–53, 2021. [Online]. Available: DOI: 10.1007/s13735-021-00206-5

[66] E. Duque, G. Fonseca, H. Vieira, G. Gontijo, and L. Ishitani, "A systematic literature review on user centered design and participatory design with older people," in *Proceedings of the 18th Brazilian Symposium on Human Factors in Computing Systems*, ser. IHC '19. New York, NY, USA: Association for Computing Machinery, 2019. [Online]. Available: DOI: 10.1145/3357155.3358471

[67] S. Kujala and M. Kauppinen, "Identifying and selecting users for user-centered design," in *Proceedings of the Third Nordic Conference on Human-Computer Interaction*, ser. NordiCHI '04. New York, NY, USA: Association for Computing Machinery, 2004, p. 297–303. [Online]. Available: DOI: 10.1145/1028014.1028060

[68] N. R. Turner and C. Berridge, "How I want technology used in my care: Learning from documented choices of people living with dementia using a dyadic decision making tool," *Informatics for Health and Social Care*, vol. 48, no. 4, pp. 387–401, 2023, pMID: 37675938. [Online]. Available: DOI: 10.1080/17538157.2023.2252066

[69] C. Berridge, N. R. Turner, L. Liu, K. I. Fredriksen-Goldsen, K. S. Lyons, G. Demiris, J. Kaye, and W. B. Lober, "Preliminary Efficacy of Let's Talk Tech: Technology Use Planning for Dementia Care Dyads," *Innovation in Aging*, vol. 7, no. 3, p. igad018, 03 2023. [Online]. Available: DOI: 10.1093/geroni/igad018

[70] A. T. Cathy Treadaway and J. Fennell, "Compassionate design for dementia care," *International Journal of Design Creativity and Innovation*, vol. 7, no. 3, pp. 144–157, 2019. [Online]. Available: DOI: 10.1080/21650349.2018.1501280

[71] F. D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology," *MIS Quarterly*, vol. 13, no. 3, pp. 319–340, 1989. [Online]. Available: DOI: 10.2307/249008

[72] V. Venkatesh, M. G. Morris, G. B. Davis, and F. D. Davis, "User acceptance of information technology: Toward a unified view," *MIS Quarterly*, vol. 27, no. 3, pp. 425–478, 2003. [Online]. Available: DOI: 10.2307/30036540

[73] A. A. AlQudah, M. Al-Emran, and K. Shaalan, "Technology acceptance in healthcare: A systematic review," *Applied Sciences*, vol. 11, no. 22, 2021. [Online]. Available: DOI: 10.3390/app112210537

[74] B. Bennett, F. McDonald, E. Beattie, T. Carney, I. Freckelton, B. P. White, and L. Willmott, "Assistive technologies for people with dementia: ethical considerations," *Bulletin of The World Health Organization*, vol. 95, no. 11, pp. 749–755, 5 2017. [Online]. Available: DOI: 10.2471/blt.16.187484

[75] J. M. Robillard, I. Cleland, J. Hoey, and C. Nugent, "Ethical adoption: A new imperative in the development of technology for dementia," *Alzheimer's & Dementia*, vol. 14, no. 9, pp. 1104–1113, 2018. [Online]. Available: DOI: 10.1016/j.jalz.2018.04.012

[76] M. Tauber, B. Gollan, C. Schmittner, and T. Ballhausen, "Social inclusion, health and content," *ERCIM News*, pp. 9–10, 2022

Fabian Simmank works as a Key Researcher at Research Studios Austria Forschungsgesellschaft. He received his PhDs in human biology and economics investigating neural correlates of human behavior in judgment and decision tasks, resp. in moral economic paradigms concerning social value orientation. He has worked on a range of research and consulting projects in the scope of marketing, health, and human factors bridging neuroscientific and psychological approaches to derive relevant insights for industry and consumers.

Katarzyna Grebosz-Haring is currently a Senior Scientist in the Inter-University Organization Arts and Knowledges, Paris Lodron University of Salzburg / Mozarteum University Salzburg and at the Department of Art History, Musicology and Dance Studies at the Paris Lodron University of Salzburg. She studied music pedagogy, music therapy, violin and music and movement pedagogy in Poland and Austria, received her doctorate in musicology at the Mozarteum University Salzburg and habilitated in systematic musicology at the Paris Lodron University of Salzburg. She is director of the Salzburg Institute for Arts in Medicine (SIAM) and co-chair of the International Network for the Critical Appraisal of Arts and Health Research. Psychophysiological, socio-psychological and aesthetic issues of music and arts with special reference to vulnerable groups, such as children and young people with mental illnesses or older people with neurodegenerative diseases are in the centre of her research interests. More: https://scholar.google.com/citations?user=w0sOp48AAAAJ

Thomas Ballhausen is a writer, philosopher and university lecturer at the Institute of Open Arts at Mozarteum University Salzburg. His current research interests include Comparative Media Studies, (Post-) Digitality and Language-Based Artistic Research. In addition to his work in European research contexts, Ballhausen has repeatedly and successfully engaged in interdisciplinary collaborations in fields as diverse as film, music, and new media art. Among his most recent publications are the monographs Nachtaktiv. Versuch über das Cahier“ (2023) and Fiction Fiction. Language Arts and the Practice of Spatial Storytelling“ (together with E. Peytchinska; 2023).

Christian Thomay received his diploma degree in physics from the University of Vienna in 2011 and his PhD in experimental particle physics from the University of Bristol in 2015. He is currently leading the studio Pervasive Computing Applications at the Research Studios Austria FG as Operative Studio Director. In this role, he has worked on a range of research projects in the scope of pervasive computing and attention-aware systems, including projects enhancing flight pilot training towards support using evidence-based performance and attention metrics, industrial assistance systems, and data science projects analzying large amounts of sensor data in medical use-cases, such as robotic-assisted physical therapy and medical training systems.

Martin Biallas is a lecturer at the iHomeLab, part of the Lucerne University of Applied Sciences and Arts. He specializes in assistive technologies, human-system interaction, and physiological monitoring, focusing on innovative solutions that emphasize interdisciplinary collaboration and ethical, user-centered design. He earned his Dipl.-Ing. (TH) degree in electrical engineering and communication technologies, with a specialization in biomedical engineering, from the University of Karlsruhe (TH). Later, in 2011, he completed his Dr. sc. ETH degree in biomedical engineering at the Swiss Federal Institute of Technology (ETH Zurich).

Markus Tauber works as Chief Scientific Officer at Research Studios Austria Forschungsgesellschaft. Between 2015 until 2021, he worked as FH-Professor for the University of Applied Sciences Burgenland, where he held the position: director of the MSc program “Cloud Computing Engineering” and led the research center “Cloud and Cyber-Physical Systems Security”. From 2012 until 2015, he worked at the Austrian Institute of Technology (AIT). Amongst other activities, he was the coordinator of the FP7 Project “Secure Cloud computing for CRitical infrastructure IT” - (www.seccrit.eu). From 2004 to 2012, he was working at the University of St Andrews (UK), where he worked as a researcher on various topics in the area of network and distributed systems and was awarded a PhD in Computer Science for which he was working on “Autonomic Management in Distributed Storage Systems”.

Navigating in the Law of Digital Reality: Contractual and Jurisdictional Challenges in a Borderless World

Barna Arnold Keserű[1]

***Abstract*—The Law of Digital Reality can be defined as a confluence of various existing aspects of private law and public law (or their intersection), which regulates the rights and obligations of the users and the service providers both within and outside of the digital world in respect of their activities related to the digital reality and establishes the legal framework for creating and maintaining such a digital environment. To comprehend the Law of Digital Reality it is essential to recognize that participation in any kind of digital reality constitutes a contractual relationship between the user and the service provider. However, the users do not conclude contract with each other, their relationships are non-contractual. Any violation of rights among the users, therefore, occurs on a non-contractual basis. This distinction fundamentally influences the obligations of service providers and users, and their potential claims in the case of violation of rights. Given that legal systems are territorial and national entities (with the EU being a regional exception), it is necessary to address the question of which law is applicable to the aforementioned legal relationships. The article aims to summarize the potential solutions for determining jurisdiction and identifying the applicable law. This will also highlight that there are no universal answers to legal questions in the context of a geographically unlimited phenomena.**

***Index Terms*—Virtual reality, Augmented reality, Digital Reality, Contract law, Law enforcement, Consumer protection**

I. Introduction

The Internet is one of the greatest inventions of mankind. Not merely an invention, but a truly earthshaking innovation as defined by J. Schumpeter. According to Schumpeter, innovation involves a new combination of existing economic foundations and forces, what is able to create new needs and consumer habits. The purpose of innovation, within this framework, is not merely to satisfy existing needs but to fundamentally alter them. In doing so, innovation transforms widely accepted human values. Schumpeter identified five types of innovations: (a) the creation of a new product or the improvement of an existing one, (b) the development of new industrial processes, (c) the establishment of a new market, (d) the discovery of new independent resources, and (e) the foundation of a new organizational structure.[1]

The emergence of Internet in the 1990s has changed the life of everyday fundamentally. New ways of consuming have become widespread, new types of entertainment have taken over the leading role, and new methods of working (both in industry and service providing) determine our life. At the core of these developments is the Internet's ability to establish new connections in public and private networks and to facilitate the near-instantaneous transfer of data between people. Where new possibilities arise, so too do new risks. The legal system must find adequate legal solutions in order to support the exploitation of new possibilities, while also establishing a framework to mitigate the associated risks and challenges.

The virtual world is one of the consequences of the technological advancements driven by the increasing global accessibility of the Internet.

In October 2021, Mark Zuckerberg announced that Facebook would be rebranded as Meta. The new name reflects the new era what Mark Zuckerberg envisions through his social media platforms. The proposed future is a “metaverse” rather than a mere social media platform. In order to create the metaverse, the company has invested $36 billion since 2019, demonstrating the significance and scale of this development. Meta seeks to establish a new virtual and augmented reality environment where realistic avatars represent users engaging in various activities—such as playing, working, training, learning, or other endeavors—within the 3D metaverse.[2] This phenomenon deserves thorough sociological research due to the significant effects and potential risks on human behavior and lifestyle. Recently, however, the development of the metaverse has been notably overshadowed, primarily due to the high costs of development, slow technical progress, and the expensive tools required for its further enhancement. Large technology companies, including Meta, are currently focusing more on exploiting artificial intelligence. Nevertheless, legal analysis of the metaverse remains crucial, as technological breakthroughs can occur at any time and the law should be prepared to address them swiftly.

The main goal of this article is to establish a comprehensive framework for the Law of Digital Reality (hereinafter referred to as LoDR), which encompasses the legal rights and obligations of users and service providers within digital environments. LoDR is not merely a specialized legal subtopic for computer games but an increasingly important field of law that intersects with various areas of private and public law. By defining the scope and structure of LoDR, this study aims to provide a guideline of how legal principles can be applied to the unique challenges posed by digital realities.

Date of submission: 15.07.2024.
[1]Associate Professor, Head of Civil Law and Civil Procedural Law Department, Széchenyi István University, Győr, Hungary. (E-mail: keseru.barna@ga.sze.hu)

DOI: 10.36244/ICJ.2025.6.7

The research is motivated by the urgent need to address the legal ambiguities and complexities that continuously arise in digital environments. As digital realities become more pervasive, the lack of a clear legal framework may result significant risks for users, service providers, and other stakeholders. Issues regarding virtual property rights, contractual relationships, jurisdictional conflicts, and the protection of personal data in digital spaces require immediate attention. Without a proper legal framework, the potential for abuse and legal disputes in digital realities will only grow, undermining the benefits of these innovative technologies.

This study distinguishes itself by framing LoDR as a comprehensive legal field that goes beyond the narrow focus on virtual property or gaming-related issues. While previous research has explored specific aspects of virtual reality (as it will be demonstrated below), such as intellectual property rights or contractual obligations, this article seeks to synthesize these areas into a unified framework. By examining the legal relationships between users, service providers, and other actors in digital realities, this research offers a new perspective on how existing legal principles can be adapted to tackle the unique challenges of digital environments. Furthermore, this study identifies the need for new legal definitions and dispute resolution mechanisms tailored to the complexities of digital realities.

In general, the primary challenge in developing LoDR is to reconcile the borderless nature of digital reality with the territorial nature of legal systems. Digital environments can operate across borders, making it difficult to determine which jurisdiction's laws apply to disputes occurring within these platforms. Moreover, the contractual relationships between users and service providers, as well as the non-contractual interactions among users, raise complex legal questions that are not adequately resolved by existing laws. For example, the recognition of virtual property rights, the enforcement of contractual terms, and the protection of users' privacy and identity in digital spaces all require innovative legal solutions. These challenges underpin the need for a flexible and adaptive legal framework which can keep pace with technological advancements.

The study begins by examining the concepts of reality and digital reality, as a clear understanding of these terms is essential for interpreting potential legal frameworks. Subsequently, potential definition of LoDR is presented, along with a synthesis of the legal branches and inquiries that constitute the corpus of LoDR. The third section of the article explores the nature of legal relationships between actors in the metaverse, as these relationships are fundamental to the structure and core elements of LoDR. Finally, the study seeks to determine how the boundlessness of digital reality can be managed within the constraints of a legal system operating within physical boundaries.

II. Research methods

This paper falls within the domain of law and does not engage deeply with informatic issues through the lens of STEM disciplines. Instead, it relies on basic and widely accepted notions of virtual and digital reality to provide a contextual foundation for legal assessment without challenging these concepts. The primary methods of investigation are governed by doctrinal jurisprudence. The first part of the research is historical and philosophical in nature, exploring scientific theories on reality. The second part of the study focuses on the framework of LoDR and practical implications related to legal issues of metaverse. Throughout the paper, a legal dogmatic approach and text-based qualitative analysis are applied. The legal research methodology includes a systematic examination of statutory provisions and scientific literature relevant to the topic. Legal hermeneutics is utilized to interpret legislative texts and case law, ensuring a thorough understanding of the legal principles and doctrines involved. Furthermore, the research incorporates doctrinal analysis to assess scholarly opinions and theoretical perspectives on the relevant issues. By integrating these methodologies, the study provides a comprehensive analysis of the legal framework governing the metaverse.

III. Definition of Digital Reality

Defining the LoDR necessitates first defining the concept of Digital Reality. The initial question is how we apprehend reality. Is reality, by definition, a non-digital phenomenon, with its digital counterpart representing an advancement? Or does reality exist in multiple forms, all distinct from the imaginary? Describing reality is inherently complex and primarily falls within the domain of philosophy. The most elementary definitions can be found in dictionaries, such as the following: “The state of things as they actually exist, as opposed to an idealistic or notional idea of them”[3], “the true situation and the problems that actually exist in life, in contrast to how you would like life to be”[4], “the state of things as they are, rather than as they are imagined to be”[5].

From a philosophical perspective it is essential to emphasize the role of Plato, the great Greek philosopher, who articulated his famous cave metaphor concerning life and knowledge. In In Plato's view, our usual existence closely resembles a prison. Our environment as we perceive it is similar to shadows. Behind these shadows lie the more noble ideas. According to Plato, ideas are posited wherever we use the same name for a certain set of individual things. Ideas represent the general forms or species of existence. However, ideas are not mere general abstractions, they constitute the only true metaphysical reality. Individual things are ephemeral, while ideas are the eternal archetypes of things, which will never vanish. One of the fundamental philosophical questions is which has a higher level of reality: the general or the individual? According to Plato ideas constitute true reality, whereas individual things are imperfect replicas.[6]

Aristotle had a different perspective. Unlike Plato, he did not follow the above argument that the general is an abstract idea with a privileged reality. Instead, Aristotle posited that the general is the common essence of existing individual objects. Later in the medieval period the unversialia debate (universialia is the general notion behind the unique objects) resurfaced again. Theorists sought to determine whether general notions possess reality. During the age of scholastic philosophy, two main theories emerged: realism and nominalism. Realism has meant that the higher level of reality is attributed to general terms as opposed to individual things. (It is important to note that contemporary realism refers to the opposite: today, a realist

acknowledges only the physical and temporal surroundings. In this sense, scholastic realism would today be considered idealism.) In contrast, proponents of nominalism argued that general terms do not have real existence; only individual entities do, and general notions exist solely in our minds as names for different things. These two theories are encapsulated in the theses "Universialia ante rem" and "Universialia post rem". Pierre Abélard synthesized these positions with his theory of "Universialia in rebus". He argued that general ideas cannot be artificially separated from individual objects because the general notion exists always within the particular thing.[7] In the early 19th century, Hegel developed his own logic concerning the dialectic of existence and nothingness, which are connected through being, expanding this framework to culminate in the concept of the ultimate spirit.

This basic summary highlights that reality has always been central to philosophical thought. Based on the contemporary infocommunication science reality can be interpreted "as a set of conceptions and perceptions that form an integrated unit of comprehension, and create an understanding of what is possible, desirable and actual."[8] It is important to note that, from Plato through the scholastic theorists to the present notion, reality has consistently been connected to the human mind and cognitive faculties of understanding. Reality needs to be perceptible.

Another fundamental question is the definition of virtuality. Typically, virtuality is used as the counterpart to real things. Virtual entities do not exist in reality as physical objects but manifest without any material substance. According to Baranyi et al. we can "consider any manifestation to be 'virtual' that has a referential aspect, regardless of whether that manifestation appears purely in someone's imagination, or in a specific physical or digital solution, and regardless of whether it points to a real (physical) or a purely imaginary concept, or to a specific, concrete object (i.e. an instantiation of a concept)."[9] Reality exists in many forms, varying by degree of physicality. A common concept is augmented reality (or extended reality, mixed reality) which involves visually represented objects within the physical environment. In contrast, virtual reality "can be conceived of as any artificially constructed environment (whether physical or digital) that contains virtual objects."[10]

Baranyi et al. define digital reality as a high-level integration of virtual reality, artificial intelligence, and 2D digital environments. This represents a highly contextual reality for humans, offering a wide range of possible application. The Internet of Digital Reality (IoD) refers an interoperable environment for digital realities, where they are connected in a harmonized network. It has numerous technological prerequisites, one of which is the importance of artificial intelligence and the possibility of high level of connectivity. The metaverse, as a form of IoD was thoroughly explored by Wersényi in 2023.[11]

The multilevel connection provides new advanced functionality in the integrated cyber space, raising a growing number of technological and legal questions. In this article the author discusses the scope of LoDR and its basic structural attributes based on the above definitions.

IV. The Scope of Law of Digital Reality (LoDR)

The legal assessment of digital reality originates from the video game industry.

The video game industry plays a leading role among creative industries due to its substantial global revenue generation. Many video games offer players the opportunity to create or collect items ranging from common to extremely rare. In the online world, these unique assets acquire value through the multiplayer system of the games. While players can trade these assets for virtual currency within the game, this becomes more legally intriguing when these assets are sold for real money. For example, in *The Sims Online* (which servers has been already shut down) players could purchase prebuilt houses from in-game real estate agents, allowing them to save time on building and designing. The virtual homes gained a real-world value.[12]

Games that allow the direct or indirect transfer of an object (an item, a character, or a complete account) from one player to another can lead to real money transactions. This raises the legal question, that a virtual item can be sold like a real object? Can it be the subject of a sales contract? Can virtual property be considered a form of property? These were among the first legal questions posed by virtual reality, but they are certainly not the last.

New fields of law continuously emerge alongside the technological development. The concept of digital reality raises many legal questions, particularly regarding how to apply laws designed for the offline world in the digital era. Do we need new legislation, or will courts reinterpret existing laws to address these new challenges?

The legal evaluation of the law of virtual reality is not new in jurisprudence. In 1994, J. Russo and M. Risch published their article entitled "The Law of Virtual Reality. Scope of Protection for Virtual Works" in Computer Software Treatise. Three decades ago, Russo and Risch investigated virtual reality from the aspect of copyright law, highlighting the importance of intellectual property protection even in the early years of virtual reality.[13] In 2004, F. G. Lastowka and D. Hunter published their often-cited article in California Law Review with the title of "The Laws of the Virtual Worlds". They argued that laws of virtual worlds are significant for three main reasons. First, virtual reality attracts continuously growing number of participants. At that time, the platform named "There" was in beta testing, what was not a gaming environment, but a virtual place for everyday living. Second, as illustrated by "There", the boundaries between the virtual and real worlds were increasingly fading. Microtransactions in virtual realities for real money have a significant economic impact. Third, the exploration of virtual world laws was important because these worlds provide parallel, alternative legal systems where new forms of social regulation emerge.[14] The focus of Lastowka and Hunter's research was on the applicability of property rights to virtual assets. In the last decade and a half, the primary research topic in legal literature has been the property issues of virtual worlds, although many other areas are increasingly being explored. Recently, Nekit argued that social media accounts are multifaceted, encompassing contractual, intellectual property, and property aspects. According to Nekit, these accounts can be considered a form of virtual property as they meet its defining characteristics.[15] Ramirez-Montes investigated the significant rise in metaverse-based EU trademark applications, which poses new challenges for EU tribunals when they apply the trademark law provisions and

theories in the metaverse.[16] As online fraudulent activities become more widespread, metaverse-related cybercrimes are also frequently discussed in the relevant literature.[17] [18] As can be seen, the literature on virtual reality is diverse among scholars; therefore the following table summarizes the key contributions of a few authors to illustrate the development of scientific comprehension.

TABLE I
OVERVIEW OF THE RELEVANT LITERATURE. COMPILED BY THE AUTHOR.

Name of the Author	Main contribution
Castronova, Edward	Analyzed the economic value of virtual worlds through the example of Norrath in the game called Everquest [19]
Fairfield, Joshua	Defined virtual property as a rivalrous, persistent, and interconnected code that mimics real world characteristics [20]
Blazer, Charles	Added secondary market value and "value-added-by-users" attributes to Fairfield's characteristics [21]
DaCunha, Nelson	Identified virtual property as Fairfield, but added the transferability requirement [22]
Nelson, John William	Argued against virtual property. It is created by developers; granting rights to users reduces the developers' control [23]
Sheldon, David P.	Emphasizes the contractual nature and limitations of virtual property [24]

If we aim to define LoDR, we must first identify and map all relevant legal aspects of digital reality, which can serve as the foundation of abstract definition. The following tables outline various (though not exhaustive) fields of law that are implicated by one or more legal issues in the digital reality, along with some examples:

TABLE II
LEGAL MAP OF DIGITAL REALITY. COMPILED BY THE AUTHOR.

Private law in Digital Reality	
Legal fields	**Examples of issues**
Personality rights	Extension of private life in the digital world; freedom of expression and hate speech; abuse of identity
Property law	Possibilities of virtual property; property-like rights of users
Contractual law	Right and obligations of the users and services providers, the whole system will be covered by general terms and conditions; unfair terms in the digital sphere
Inheritance law	Possibility to inherit the "virtual property" or other values in the digital reality
Family law	Digital reality as a scene for child-parent contact
Intellectual property law	Digital reality is an intellectual property per se; trademark, copyright or design infringement in the digital reality; copyright aspects of interoperability; IP rights of user generated contents; IP rights on virtual objects
International private law	Digital reality is a cross-border phenomenon, and every aspect of it may raise jurisdiction questions

Public law in Digital Reality	
Legal fields	**Examples of issues**
Financial and tax law	Where and how to pay taxes on revenues generated by digital reality – tax avoidance; taxation on sales in digital reality; cryptocurrencies; money transfer within digital reality
Criminal law	Cybercrimes against users or against the platform
Administrative law	Regulation of establishment and maintenance of digital reality; accounting the principles of application of artificial intelligence; transparency of the operations
Procedural laws	Proof of facts in digital reality in criminal or civil procedures

Mixed fields of law in Digital Reality	
Legal fields	**Examples of issues**
Consumer protection law	Effective mechanisms of complaints; dispute resolution mechanisms; mitigation against addiction; protection of younglings
Data protection law	The protection of every data generated in the digital reality; profiling of the users
Competition law	Cartels, merger control and monopoly of the service providers; abuse of dominant position by big service providers; unfair influence on decision making of consumers; unfair competition in the digital reality
Labor law	Employment in the digital reality; digital workplaces
Advertising law	Digital reality as an infinite commercial board; regulation and check of the cross-border commercials in the digital reality
Media- and entertainment law	Audiovisual media contents and their national requirements in the digital reality; e-sport in digital reality;

Based on the above lists, LoDR can be defined as a combination of various existing aspects of private and public law, or their intersection, that regulate the rights and obligations of users and service providers within and outside the digital world concerning their activities related to digital reality and establishes the legal framework for creating and maintaining such a digital reality. LoDR can be further supported by soft law instruments, such as development policies, codes of conduct, principles for developers, and best practice guides, which serve as detailed tools for implementing the otherwise abstract legal regulations.[25]

V. The Contractual Aspects of Digital Reality

The starting point of understanding LoDR is to comprehend the structure of legal relationships within digital reality. First, it is important to emphasize, that digital reality is an artificial construct. It does not exist without a service provider. While in the physical world, individuals can act independently according to their own will through the biomechanical processes of their bodies, this is impossible in digital reality. Every element of digital reality is created and provided by a service provider.

Legal relationships can be broadly categorized as absolute structure and relative structure. In an absolute structured legal relationship, there is one or a few known right holders and an unlimited number of unknown obligees, each with three negative obligations: to respect the right of the right holder, not to interfere with the exercise of that right, and to bear the exercise of that right. In contrast, relative structured relationships involve mutual rights and obligations between known and identified parties. In the physical world, human rights, personality rights, property rights, and intellectual property rights are examples of absolute rights (historically property is the archetype of them), which are granted by the law, and everyone has a legal obligation to respect them. Contractual relationships, on the other hand, have a relative structure; they bind only the contracting parties, who are exclusively entitled to the rights and obligations outlined in the contract. Contracts can be far more detailed than statutory law, and when parties cover their absolute rights within a contract, it can add many additional elements to their relationship. For example, while two individuals are legally obliged to respect each other's property and not violate it, if they enter into a lease contract, they will stipulate how, when, and to what extent the leased object can be used, and only certain breaches of contract will constitute a violation of property rights.

Considering the above principles, we must conclude that participation in any form of digital reality constitutes a contractual relationship between the user and the service provider. This relationship is governed primarily by the terms – usually general terms and conditions – provided by the service provider, and subsidiarily by the contract law of the applicable private law. Contract law should be interpreted broadly to include copyright law as well (especially rules of copyright licensing), as digital reality is always embodied in a software-created environment. Software licenses are typically governed by end-user license agreements (EULAs) between users and service providers, which are special types of general terms and conditions. In these agreements, the main service provided is access to and use of the software, while the user may (but not necessarily) be required to pay license fees and adhere to the rules of use.

Thus, the fundamental legal relationship in digital reality is contractual, what determines the application of many legal rules. In general, the special rules derogate general rules, where contracts are always more specific than the statutory law. However, there are limitations to contracts, particularly in cases of invalidity or other rules that do not permit deviation from the law. Hungarian private law is fundamentally based on the principle of contractual freedom, allowing parties to determine the contents of their contract. The parties may depart from the provisions relating to their rights and obligations with mutual consent, unless prohibited by the Civil Code.[26] This approach allows many of the questions highlighted in the above tables to be settled within the EULA, where the parties may agree on the boundaries of certain rights or even exclude the application of certain legal norms.

A few examples can briefly illustrate the mechanisms of this structure. One of the most discussed topics among legal researchers is virtual property. Generally, the recognition of property rights stems from human rights treaties (such as the Universal Declaration of Human Rights, the European Convention on Human Rights, and the International Covenant on Civil and Political Rights), which oblige member states to provide legal protection for property in their national constitutions. These rights are protected by criminal law and private law against any unlawful act. However, in a contractual relationship, the parties determine what is lawful within the framework of statutory law, and if certain aspects are not covered by statutory law, the parties can fully regulate them. If traditional property rights are not applicable to virtual items (as is the case in Hungary, where property rights can only exist for tangible things and, with certain exceptions, for intangible phenomena listed in the Civil Code), the parties may agree in the EULA to grant property-like rights to users for their virtual assets. However, these would create only contractual rights (a relative type of relationship) that bind only the contracting parties, rather than absolute rights, which would obligate everyone, as with traditional property. Therefore, a contractual analysis is always the first step in understanding the basic legal concept of digital reality. If there are no provisions in the contract regarding the 'property' rights of virtual items, then the analysis of the applicable civil law will determine the scope of possible legal assessment.

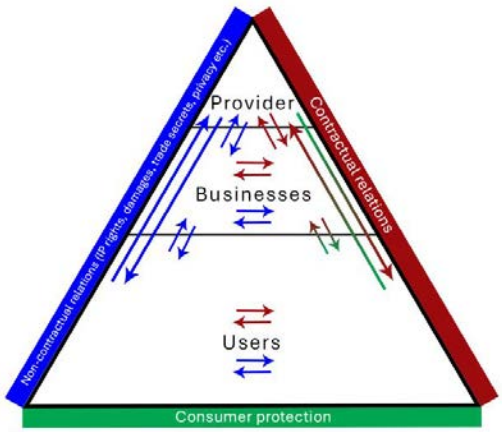
The situation is similar in the case of digital identity, secrets, and the private lives of users, as these exist only within the contractual framework of the given digital reality, albeit with respect for the unrestricted and inalienable core of fundamental rights.

The contractual relation between the user and the provider represents only one side of the coin. It is also crucial to evaluate the relationships among users, as various types of rights violations may occur in user-to-user interactions. Fundamentally, the structure is akin to that of any large social media platform. Users do not enter into contracts with each other; they merely accept the EULA. It is, of course, impossible to create contracts among every user. This distinction between user-provider and user-user relationships (which can be termed as user-to-provider/platform: U2P, and user-to-user: U2U relations) is significant. In digital reality, both U2P and U2U relations exist: U2P relations are governed by the EULA and, subsidiarily, by statutory law, whereas U2U relations are governed solely by the applicable statutory law.

EULAs, along with other policies or codes of conduct within digital reality, may serve as a bridge between U2P and U2U relations. These documents typically set forth requirements aimed at ensuring respect among users, such as prohibitions against hacking other users' profiles, sharing nudity or explicit violence, and hate speech, as well as similar ethical guidelines. These obligations are laid down within the U2P relationship but also have an impact on U2U relations. Dogmatically, these prohibitions and rules do not constitute a contractual relationship among users, so they cannot file claims against other users based on breach of contract. However, users may still file claims based on a breach of statutory law, if the law is applicable to the issue at hand in digital reality. In such cases, the violating party commits a breach of contract in the U2P relationship by failing to comply with the contractual obligation to respect other users' rights, as provided in the EULA or statutory law. Thus, violations of users' rights in U2U relations may also have consequences in U2P relations, where the provider may impose sanctions ranging from warnings to account deletion, or even take steps to initiate legal proceedings (e.g., in cases of criminal behavior).

Regulating digital reality, even through soft law instruments, plays an important role. Published guidelines, ethical principles, and best practices can motivate service providers to implement contractual measures that may prevent or restrict the violation of other users' rights.

As we delve deeper into the possibilities of digital reality, a more detailed structure with many variations emerges, where additional market actors provide built-in services (e.g., clothing shops where users can purchase items for their avatars, or professional users operating shops or restaurants within a franchise system in digital reality). These professional businesses form an additional layer in digital reality, creating further contractual relationships with users (termed as user-to-business: U2B relations) and with service providers (termed as business-to-provider: B2P relations). They may also have contractual or non-contractual relationships with each other (termed as business-to-business: B2B relations), adding complexity to the system of legal relations. Although professional businesses are also users in a sense, they often accept different EULAs than those accepted by common users. The following figure summarizes the possible structure of the legal relationships and their nature in the digital reality.



1. Figure Structure of the possible legal relations in the Digital Reality. Compiled by the author.

VI. The Cross-border Attribute of Digital Reality

Where is digital reality? Is it everywhere or nowhere? Given that legal systems are territorial and national entities (with the EU being regional), we must address the question of which law is applicable to the legal relationships described above? If the headquarter of the service provider is located in the United States of America, and its digital reality has millions of users worldwide, which law governs the functioning of this digital reality? In this context, it is also necessary to distinguish between U2P and U2U relationships, as the existence of a contract influences this question.

International private law in conflict of laws cases seeks to answer two key questions: which country has jurisdiction over a lawsuit, and which country's law will be applicable in the given case? The venue and the applicable law are crucial points in litigation concerning digital reality.

In U2P relationships, the service provider typically includes a jurisdiction clause in the terms and conditions, where the parties agree on the venue for litigation and the applicable law. In most cases, this jurisdiction is connected to the provider's home country, or in fewer cases to an independent country with flexible civil law (e.g., Switzerland), or to international arbitration courts. These options generally favor the provider, as a typical user is unlikely to file a lawsuit in a different country or at an international arbitration court due to the significant procedural and representative costs.

In this respect consumer protection regulations have to be considered, particularly in the European Union. It is crucial to determine whether EU law is applicable to the U2P relationship. In the EU the Regulation No. 1215/2012 of the European Parliament and of the Council on jurisdiction and the recognition and enforcement of judgments in civil and commercial matters (hereinafter Brussels I.) regulates the jurisdiction, if there is an international element in the given case. If the provider of the digital reality is domiciled in EU, the Brussel I. applies. Domicile can be determined by statutory seat, central administration or principal place of business.[27] U2P EULAs are generally considered consumer contracts by nature (excluding cases where professional businesses use digital reality to enhance their services, as these fall under a different legal framework without consumer protection regulations), where the user usually is a natural person acting for purposes which are outside his trade, business or profession. Article 17. of Brussels I. establishes jurisdiction over consumer contracts. The regulation extends the concept of domicile, prescribing that if a consumer enters into a contract with a party not domiciled in a Member State but having a branch, agency, or other establishment in one of the Member States, that party shall be deemed domiciled in that Member State for disputes arising from the operations of the branch, agency, or establishment. In this case the user can bring proceedings against the service provider in the Member State where the provider is domiciled or shall be deemed to be domiciled, but what is more important, the user as a consumer has the right to file the lawsuit in the courts for the place where the user is domiciled.[28] The possibility of litigating in the home court is a fundamental consumer protection rule in the EU. Conversely, if the service provider wishes to sue the user as a consumer, proceedings may only be brought in the courts of the Member State where the consumer is domiciled.[29]

The provisions described above are quite strict. According to Article 19, these provisions may only be departed from under specific circumstances: (1) by an agreement entered into after the dispute has arisen; (2) by an agreement that allows the consumer to bring proceedings in courts other than those previously indicated; or (3) by an agreement entered into by the consumer and the other party to the contract, both of whom are domiciled or habitually resident in the same Member State at the time of the contract's conclusion, which confers jurisdiction on the courts of that Member State, provided that such an agreement is not contrary to the law of that Member State. Therefore, these provisions must be carefully considered when drafting the jurisdiction clause in EULAs.

If the service provider cannot be deemed domiciled in the EU, or if the user is not a consumer, the parties are generally free to agree on the jurisdiction.

In U2U relationships - if both users are domiciled in the EU – the Brussels I. sets the rules for jurisdiction. The general rule of jurisdiction is based on the domicile of the defendant. However, Article 7. provides for special jurisdiction, allowing a person to be sued in another Member State under certain conditions:

- in matters relating to tort, delict or quasi-delict: In the courts for the place where the harmful event occurred or may occur.
- Regarding a civil claim for damages or restitution which is based on an act giving rise to criminal proceedings: In the court seized of those proceedings, to the extent that that court has jurisdiction under its own law to entertain civil proceedings.

The above situations may arise in cases of rights violations in U2U relationships. If not all litigating users are domiciled in the EU, then the international private law of the relevant countries may provide jurisdiction rules; however, these suits are often not cost-effective.

The geographically unlimited nature of digital reality may undermine the protection of personality rights or property rights of users due to the complexity and expense of international litigation. Therefore, as a best practice, the author recommends incorporating an internal alternative dispute resolution (ADR) mechanism into digital reality specifically dedicated to U2U disputes. By accepting the EULA, users should also accept the jurisdiction of this ADR body, without prejudice to their right to litigate in real courts. This method would primarily be suitable for stopping ongoing violations, although monetary remedies might be beyond its capabilities.

Another important factor, alongside the venue of litigation, is the determination of the applicable law. If a user has a claim based on a breach of contract, violation of personality rights, or infringement of intellectual property rights, the applicable law will largely determine the potential outcomes of such claims. For example, the regulation and case law regarding personality rights or the recognition of virtual property can differ significantly between common law and civil law countries. Each legal system has its own unique characteristics, making it impossible to provide general answers to substantive legal questions concerning digital reality. As the saying goes, 'it always depends.' The results may vary from one legal system to another. Within the EU the Regulation No. 593/2008 of the European Parliament and of the Council on the law applicable to contractual obligations (hereinafter Rome I.) and the Regulation No. 864/2007 of the European Parliament and of the Council on the law applicable to non-contractual obligations (hereinafter Rome II.) govern these issues. While a comprehensive analysis of these regulations is beyond the scope of this article, it can generally be concluded that, by their nature, Rome I. is likely applicable to U2P relations involving contracts, whereas Rome II. may apply to U2U relations where no contracts exist among the users.

Rome I. establishes the principle of freedom of choice of law, and in the absence of such a choice, it provides provisions for determining the applicable law. The contract between the user and the service provider is atypical, combining elements from various types of contracts, but it falls under the scope of Rome I. According to Rome I, a contract for the provision of services is generally governed by the law of the country where the service provider has their habitual residence. However, if the user is a consumer, the contract shall be governed by the law of the country where the consumer resides, provided that the professional pursues their commercial or professional activities in the country where the consumer has his habitual residence, or by any means, directs such activities to that country or to several countries including that country and the contract falls within the scope of such activities.[30] Parties may choose the law applicable to a contract meeting these conditions, but such a choice cannot deprive the consumer of the protection afforded by provisions that cannot be derogated from by agreement under the law that would otherwise apply in the absence of choice.

Contracts in U2B, B2B, and B2P relationships must also be categorized, as they may be governed by different principles under Rome I. For example, franchise contracts in digital reality are generally governed by the law of the country where the franchisee has their habitual residence, while contracts that provide essential access to and use of digital reality may be governed by different laws.

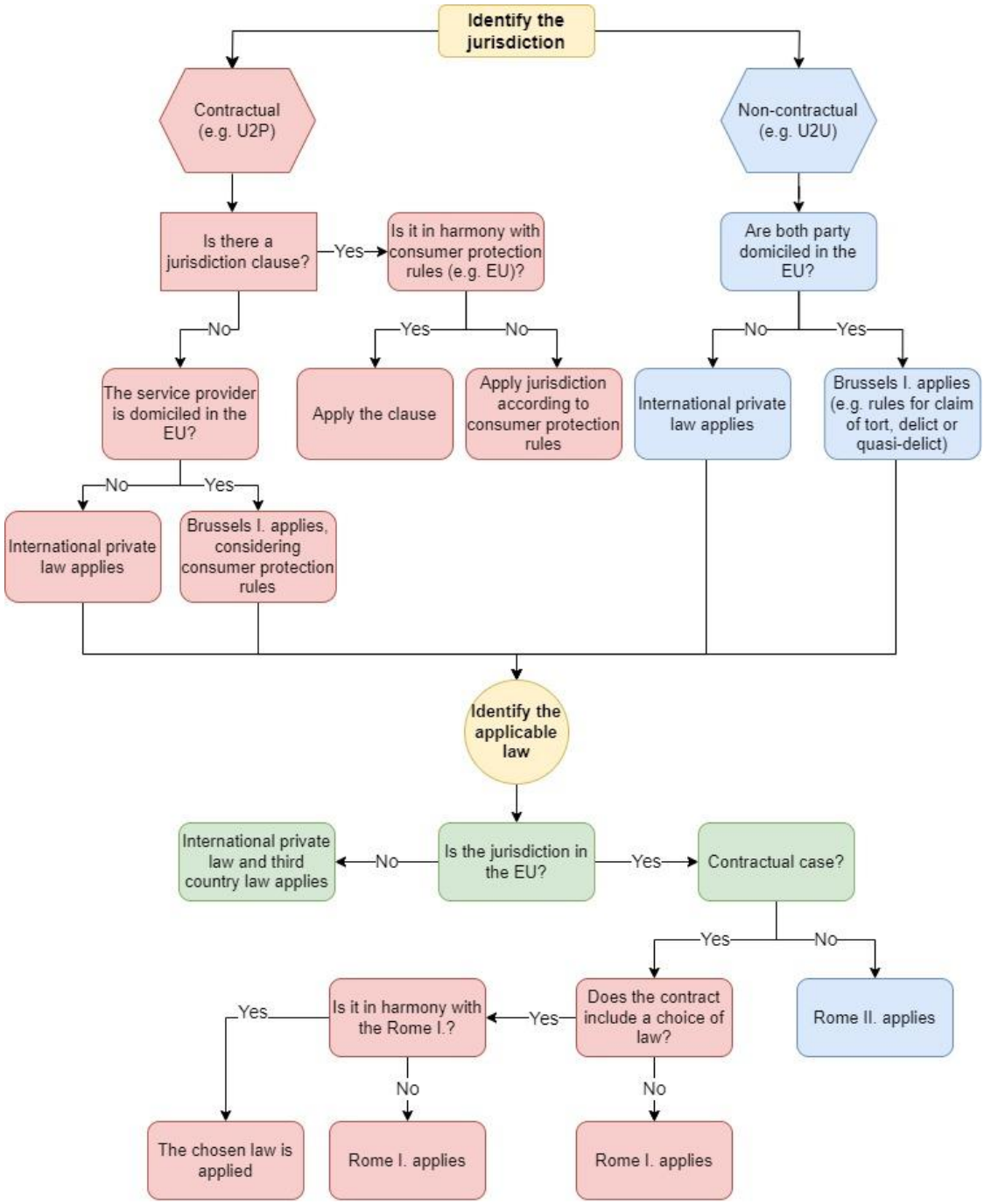
Rome II. provides provisions for determining the applicable law in cases involving torts, unfair competition, or infringement of intellectual property rights, among others. Many of these rules are challenging to interpret in the context of digital reality, and case law is needed to apply them effectively to the Internet. Issues such as the location of damage, unfair competition in digital reality, and the territorial nature of intellectual property rights raise several complex questions regarding digital reality.

VII. Conclusion

In the past two decades, numerous studies have explored the questions surrounding virtual reality, particularly the concept of virtual property. This paper aims to revisit the foundational issues, as even at the starting point, there are essential questions that must be addressed to advance our understanding. It is crucial to map the possible types of legal relationships, understand their nature, and identify the applicable laws that will govern these relations. Digital reality is continuously evolving. From the early stages of virtual and augmented reality, technology has advanced significantly. If metaverses like Meta are successfully launched, the legal relationships within the digital world will exponentially multiply, potentially replicating the full complexity of real life in digital reality.

Policymakers should work towards establishing clear legal definitions for various assets within digital reality, such as social media accounts, virtual property, and digital identities. The lack of consistent terminology and legal recognition across jurisdictions can lead to uncertainty and hinder the protection of users' rights. Establishing these definitions in legislation will provide a solid foundation for addressing disputes and managing digital assets effectively. Legal frameworks should incorporate enhanced dispute resolution mechanisms that are accessible and efficient for resolving conflicts in digital reality. This could include specialized digital courts or alternative dispute resolution (ADR) methods designed to handle the unique challenges of virtual interactions.

This article provides a basic scheme for legal relations and applicable legal systems in order to support the further exploration of digital reality.



2. Figure Flowchart of identifying jurisdiction and applicable law related to Digital Realities. Compiled by the author.

References

[1] Schumpeter, J., "*A gazdasági fejlődés elmélete*", Budapest, Hungary, Közgazdasági és Jogi Könyvkiadó, 1980, pp. 110–111.
[2] "Meta lett a Facebookból – milyen lesz a Zuckerberg által álmodott virtuális világ?" *Forbes*, 29.10.2021., available at https://forbes.hu/uzlet/meta-facebook-metaverzum-video/.
[3] *LEXICO*, available at https://www.lexico.com/definition/reality.
[4] *Oxford Learner's Dictionaries*, available at https://www.oxfordlearnersdictionaries.com/definition/american_english/ reality
[5] *Cambridge Dictionary*, available at https://dictionary.cambridge.org/dictionary/english/reality
[6] Störig, H. J., "*A filozófia világtörténete*". Helikon, Budapest, 2006, p. 125.
[7] Störig, H. J., "*A filozófia világtörténete*". Helikon, Budapest, 2006, pp. 187–192.
[8] Baranyi, P. – Csapó, Á. – Budai, T. – Wersényi, Gy., "Introducing the Concept of Internet of Digital Reality, Part I.," *Acta Polytechnica Hungarica*, 2021/7., p. 226., DOI: 10.12700/APH.18.7.2021.7.12, available at: http://acta.uni-obuda.hu/Baranyi_Csapo_Budai_Wersenyi_114.pdf
[9] Baranyi, P. – Csapó, Á. – Budai, T. – Wersényi, Gy., "Introducing the Concept of Internet of Digital Reality, Part I.," *Acta Polytechnica Hungarica*, 2021/7., p. 227., DOI: 10.12700/APH.18.7.2021.7.12, available at: http://acta.uni-obuda.hu/Baranyi_Csapo_Budai_Wersenyi_114.pdf
[10] Baranyi, P. – Csapó, Á. – Budai, T. – Wersényi, Gy., "Introducing the Concept of Internet of Digital Reality, Part I.," *Acta Polytechnica Hungarica*, 2021/7., p. 228., DOI: 10.12700/APH.18.7.2021.7.12, available at: http://acta.uni-obuda.hu/Baranyi_Csapo_Budai_Wersenyi_114.pdf
[11] Wersényi, Gy., "Musings on the Metaverse and on how the Internet of Digital Reality Encompasses Future Developments of the Internet", *Infocommunications Journal, Special Issue: Internet of Digital & Cognitive realities*, 2023, pp. 21–28., DOI: 10.36244/ICJ.2023.SI-IODCR.4
[12] Eszteri, D., *"A World of Warcraft-tól a Bitcoin-ig: Az egyén, a gazdaság és a tulajdon helyzetének magán-és büntetőjogi elemzése a virtuális közösségekben"*, PhD dissertation, 2015, Pécs, p. 69–77.
[13] Russo, J. – Risch, M., "The Law of Virtual Reality. Scope of Protection for Virtual Works," in *Computer Law Treatise*, 1994, available at: https://www.computerlaw.com/articles/the-law-of-virtual-reality/
[14] Lastowka, F. G. – Hunter, D., "The Laws of the Virtual Worlds", in *California Law Review*, 2004, Vol. 92., No. 1., pp. 1–73., DOI: 10.2307/3481444, available at: https://www.jstor.org/stable/3481444
[15] Nekit, K., "Social Media Account as an Object of Virtual Property", in *Masaryk University Journal of Law and Technology*, 2020, Vol. 14., No. 2., pp. 1–4., DOI: 10.5817/MUJLT2020-2-3.
[16] Ramirez-Montes, C., "EU Trademarks in the Metaverse", *IDEA: The Law Review of the Franklin Pierce Center for Intellectual Property,* 2023, Vol. 63., No. 3., pp. 555–717.
[17] Haber, E. "The Criminal Metaverse", *Indiana Law Journal*, 2024, Vol. 99., No. 3., pp. 843–892.
[18] Singh, P., Rajput, D., "Metaverse: Surging Need for Competent Laws with Increasing Metaverse Crimes", *International Journal of Law Management & Humanities*, 2022, Vol. 5., No. 5., pp. 712–724.
[19] Castronova, E., "*Virtual Worlds: A First-Hand Account of Market and Society on the Cyberian Frontier"* CESifo Working Paper Series No. 618., pp. 1–40.
[20] Fairfield, J., "Virtual Property", *Boston University Law Review*, 2005, Vol. 85., p. 1053.
[21] Blazer, Ch., "The Five Indicia of Virtual Property", *Pierce Law Review*, 2006, Vol. 5., pp. 139–140.
[22] DaCunha, N. "Virtual Property, Real Concerns", *Akron Intellectual Property Journal*, 2010, Vol. 4., No. 1., pp. 41–43.
[23] Nelson, J. W., "The Virtual Property Problem: What Property Rights in Virtual Resources Might Look Like, How They Might Work and Why They Are a Bad Idea", *McGeorge Law Review,* 2010, Vol. 41., pp. 283–310.
[24] Sheldon, D. P., "Claiming Ownership, but Getting Owned: Contractual Limitations on Asserting Property Interests in Virtual Goods", *UCLA Law Review*, 2007, Vol. 54, No. 3., pp. 751–788.
[25] About the regulatory aspects see: Nogel, M. – Kovács, G. – Wersényi, Gy., "The regulation of Digital Reality in Nutshell", *12th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, 2021.
[26] Civil Code of Hungary, 6:59. § (2).
[27] Regulation No. 1215/2012 of the European Parliament and of the Council, Article 63.
[28] Regulation No. 1215/2012 of the European Parliament and of the Council, Article 17.
[29] Regulation No. 1215/2012 of the European Parliament and of the Council, Article 18.
[30] Regulation No. 593/2008 of the European Parliament and of the Council, Article 3-6.

Barna Arnold Keserű received his MSc degree in law and political sciences from Széchenyi István University, Győr, Hungary, in 2012 and received the PhD degree in law and political sciences from the same institution in 2016. In 2015, he also has completed the Advanced Course for Intellectual Property by the Hungarian Intellectual Property Office.
Since 2015, he has been a lecturer at the Civil Law and Civil Procedural Law Department of Széchenyi István University. In 2021, he was appointed as an associate professor of civil law, and in 2022, he became the head of the department. His research interests include intellectual property rights, the legal framework of technological advancements, and the legal aspects of the creative industry.
In addition to his academic career, he works as an attorney-at-law in Győr, Hungary, specializing in intellectual property law, including trademark, copyright, and patent law.

Special Issue
of the Infocommunication Journal

Introducing the New Concept of Personalized Digital Tourism (PDT)

Judit Grotte

Abstract—**The primary objective of this paper is to propose the definition of personalized digital tourism, which is a new concept in the field of tourism. This theoretical term has not been defined in the field of tourism, even though technology has been transforming travel habits for more than a decade. The article introduces the concept of Personalized Digital Tourism as a high-level integration of theories like Cognitive Infocommunications, the Internet of Digital Realities, Behavioural research of Generation Y and Z, and AI-based data handling solutions to enhance their theoretical and practical outcomes in tourism. The paper first presents the main contribution of the paper, the definition of Personalized Digital Tourism, and then it discusses the most related scientific approaches such as CogInfoCom, Generation Theories, DR, and AI. Then the paper points out these new and rapid technological advancements of recent years in the tourism industry which have resulted in a transformation of human behaviour. The paper emphasizes the necessity of achieving a more advanced conceptual grasp of the field of Tourism science.**

Index Terms—**AI-based data handling, cognitive infocommunications, generation theories, Internet of digital realities, personalized digital tourism**

I. Introduction

THE primary objective of this paper is to propose the definition of Personalized Digital Tourism (PDT), which is a new concept in the field of tourism. This theoretical term has not been defined yet, even though technology has been transforming travel habits, technological tools, and "technological habits" for more than a decade.

The main motivations behind proposing the new theoretical term PDT are as follows. First the landscape of the tourism industry has undergone rapid and substantial changes: online digital access to information, its searchability, interactivity in space and in terms of time, speed, and synchronicity with events, which is not only far more efficient but also different. Second, the process of online activities like booking or paying for accommodation, or other touristic services require special skills to develop from today's human beings.

Furthermore, the concepts, theories and various aspects of scientific approaches utilized in tourism science are also radically changing in the related fields of informatics, cognitive science, and generation science. For instance, the emergence of disciplines such as Cognitive Infocommunications, Internet of Digital Reality, Cognitive Mobility, Socio-Cognitive ICT, etc. strongly influences tourism science. Therefore, the main motivation of this paper is to introduce a concept that allows the development of a higher, more comprehensive view, which brings new concepts appearing in other related fields of science into a unified view of concepts in the scientific development of tourism.

Personalized Digital Tourism leverages cutting-edge technologies and data analytics to create a more personalized, efficient, and sustainable tourism experience. This approach not only enhances traveler satisfaction but also optimizes operations for service providers, marking a significant departure from traditional tourism models.

The definition of Personalized Digital Tourism extends far beyond the mere use of digital technology for personalization. It encompasses a sophisticated integration of cognitive science, demographic insights, immersive technologies, and advanced data analytics to create a holistic, intelligent, and highly personalized tourism experience. This multidimensional approach not only enhances individual traveler experiences but also optimizes tourism management and service quality, making PDT a comprehensive and innovative paradigm in the tourism industry.

The present paper is structured as follows: firstly, we define the novel concept of Personalized Digital Tourism, which is the main contribution of the paper Subsequently, we study - about PDT - emerging disciplines and concepts such as Cognitive Infocommunications, Generation Theories, Internet of Digital Realities, Cognitive Mobility, and AI-Based Data Handling. Finally, the conclusion of the paper is presented

II. Definition of Personalized Digital Tourism

The main objective of the section is to present the definition of PDT, then subsequently briefly summarize those recent scientific disciplines and concepts with the concept of PDT built on.

A. Definition of Personalized Digital Tourism

The concept of Personalized Digital Tourism is a novel approach that employs a combination of Cognitive Infocommunications, Generation Theories, Digital Realities, and AI-based data handling to provide tailored innovative solutions for both individual travelers and tourist service providers. PDT leverages the latest advancements in technology and data analytics to deliver customized tourism experiences that cater to the unique preferences and needs of travelers.

This approach introduces a paradigm shift in the tourism industry, enabling a more personalized and targeted approach to tourism services. By utilizing AI-based data handling, PDT provides a framework for enhancing tourism experiences,

Submitted date: 28th of March 2024.
Judit Grotte Author is with the Department of Tourism, Kodolányi János University, Budapest, Hungary (e-mail: grotte.judit@kodolanyi.hu).

DOI: 10.36244/ICJ.2025.6.8

optimizing tourism management, and improving tourism service quality. The integration of PDT into the tourism industry may lead to a significant increase in customer satisfaction and loyalty, ultimately resulting in increased revenue and profitability for tourism service providers.

III. RELATED EMERGING FIELDS

A. Cognitive Infocommunications (CogInfoCom)

The concept and the definition of Cognitive Infocommunications was emerging around 2008 at the Budapest University of Technology and Economics. It was further developed at the 1st International Conference of Cognitive Infocommunications at the Tokyo University in 2010. Later on this concept was gradually going up to be a scientific discipline having annual IEEE international conference, journal forums and books with a quite huge number of publications. The concept of CogInfoCom motivated various further branches such as Methability, Socio-Cognitive ICT, Internet of Digital & Cognitive Reality, Cognitive Mobility, Cognitive aspect of Virtual Reality, Digital & Cognitive Corporate Reality and various further approaches in digital ergonomics, digital education, AI solutions and so on.

The definition of Cognitive Infocommunications is "Cognitive Infocommunications (CogInfoCom) is an interdisciplinary field that explores the interplay between the cognitive sciences and infocommunication technologies (ICT) The primary goal of CogInfoCom is to provide a systematic view of how cognitive processes can co-evolve with infocommunications devices so that the capabilities of the human brain may not only be extended through these devices, irrespective of geographical distance but may also be blended with the capabilities of any artificially cognitive system. This merging and extension of cognitive capabilities are targeted towards engineering applications in which artificial and/or natural cognitive systems are enabled to work together more effectively." [9]

The key point of CogInfoCom is that it does not view the digital environment and humans in interaction in between, but rather considers the blended combination of human and digital environment as one cognitive entity (CE) [14] with high-level entangled combination of natural and artificial cognitive capabilities. It is motivated by the fact that the border between the human and digital environment is disappearing. Thus CogInfoCom researches new cognitive capabilities of the CE.

Cognitive Infocommunications deals with the effects of rapid technological advancements on human behavior and communication patterns. These changes have led to the emergence of a "New Human," necessitating a deeper understanding of their communication habits and behaviors to improve service delivery in the tourism industry. Therefore, businesses in the tourism sector must comprehend the new patterns of communication and behavior to offer personalized services to their customers.

B. Internet of Digital & Cognitive Reality (IoD)

This concept of Internet of Digital & Cognitive Reality (IoD) is motivated by the fact that the digital environment, internet, and humans form a borderless huge "ocean" of combined natural and artificial cognitive capabilities. This concept focuses on realities as components or well-definable parts of this "ocean". It also approaches the digital transformation as a track of evolutionary milestones of DOS, Windows, and Spaces such as VR, XR, AR , digital twins etc.

The definition of Digital Reality is as follows: [11][12][13][14]:

"A Digital Reality (DR) is a high-level integration of virtual reality (including augmented reality, virtual and digital simulations and twins), artificial intelligence, and 2D digital environments which creates a highly contextual reality for humans in which previously disparate realms of human experience are brought together. DR encompasses not only industrial applications but also helps increase productivity in all corners of life (both physical and digital), thereby enabling the development of new social entities and structures, such as 3D digital universities, 3D businesses, 3D governance, 3D web-based digital entertainment, 3D collaborative sites and marketplaces."

The definition of Digital Reality was extended to Internet of Digital and Cognitive Reality (IoD) in [15][16] as

"The Internet of Digital Reality (IoD) is a set of technologies that enables digital realities to be managed, transmitted and harmonized in networked environments (both public and private), focusing on a higher level of user accessibility, immersiveness and experience with the help of virtual reality and artificial intelligence."

Digital Realities: Virtual (VR) and Augmented Reality (AR). Contemporary technological advancements in virtual and augmented reality have enabled tourism businesses to create customized experiences for travelers. These technologies offer interactive and individualized services, such as personalized hotel room experiences, map functions that enable tourists to view the opening hours of attractions on a mobile phone application, gamification, beacon technology, guest recognition, maintenance information, and translation facilities. Additionally, the integration of Artificial Intelligence (AI) in tourism businesses has facilitated data collection, analysis, and handling more efficiently and effectively. As a result, tourism businesses can now offer travelers tailored experiences that cater to their individual preferences, thus significantly enhancing the overall tourism experience [6]. According to Baranyi "a Digital Reality (DR) is a high-level integration of virtual reality (including augmented reality, virtual and digital simulations and twins), artificial intelligence and 2D digital environments" [14][22].

The term virtual reality was introduced by Jaron Lanier [63]: an accomplished designer of immersive interface devices. In his seminal work, Heim outlined three essential characteristics of virtual reality: immersion, interactivity, and information intensity.

Lanier's [63] pioneering work in virtual reality has significantly impacted the fields of entertainment, education, and healthcare. The concept of immersion, which refers to the user's sense of being present in a virtual environment, has led to the development of advanced simulation technologies that

enable people to experience complex scenarios in a safe and controlled manner.

The prevalence of CogInfoCom solutions, which are reliant upon virtual reality, has witnessed a significant increase in recent times [44][50] Such solutions encompass the utilization of three-dimensional virtual spaces, which users can navigate through in a manner that closely resembles real-life environments. These virtual reality spaces, when employed as infocommunication tools, have the potential to aid and derive advantages from research conducted on the cognitive aspects associated with virtual reality [52][62].

Interactivity is another crucial aspect of VR, which refers to the user's ability to manipulate and interact with the virtual environment. This feature has found extensive use in gaming and training simulations, where users can practice and improve their skills in a risk-free environment.

Lastly, information intensity refers to the high degree of sensory input that a user experiences in a virtual environment. This feature has significant implications for the development of immersive educational and therapeutic applications.

Overall, the combination of immersion, interactivity, and information intensity has made virtual reality an exciting and rapidly growing field with immense potential for innovation and growth [21].

C. Generations' Theories

The study of generation theories is a subject that has captured the interest of many scientists throughout history. One of the first researchers to delve into this area was Karl Mannheim in 1928. He defined a "generation" as a group of individuals who have all experienced a significant event in history that has been tied to notable social and/or cultural transformations. This definition has been a cornerstone of generational theory research ever since [16]. The Strauss-Howe generational theory is a captivating concept that attempts to explain the cyclical nature of American and Western history. This theory posits that certain historical events are closely linked to the generational personalities of the period. In essence, it suggests that the way a generation perceives the world can have a profound impact on the course of history and shape the future of society [17].

D. Cognitive Mobility (CogMob)

The motivation behind imitating the concept of Cognitive Mobility (CogMob) is that almost all corners of the scientific discipline Mobility is influenced by the blended combination of artificial and natural cognitive capabilities. The concept of Cognitive Mobility was initiated at the Budapest University of Technology and Economics around 2020.

The definition of the CogMob is [44]

Cognitive Mobility (CogMob) investigates the entangled combination of the research areas such as mobility, transportation, vehicle engineering, social sciences, artificial intelligence, cognitive infocommunications. The key aim of CogMob is to provide a holistic view of how mobility in a broader aspect can be understood, described (modeled), and optimized as the blended combination of artificial and natural/human cognitive systems. It considers the whole combination as one inseparable CogMob system and investigates what kind of new cognitive capabilities of this Cog Mob system are emerging. One of the Cog Mob focus areas based on its nature is the engineering applications in the mobility domain.

E. Cognitive Aspects of Virtual Reality (cVR)

The research field of cVR is not mentioned explicitly in the definition of PDT. However VR, AR, XR and interactive digital twins strongly influence digital access of travelers and, further, can give an alternative way of visiting places. This is the reason why it is brief studied here:

The definition of the cVR is [57]

"Cognitive Aspects of Virtual Reality (cVR) investigates the next phases of IT evolution characterized by a transition from digital environments based on 2D graphical user interfaces (e.g. windows, images, 2D widgets) to 3D spaces which represent a higher-level integration of VR/AR/MR/Metaverse/IoD systems, human spatial cognition, the 2D digital world (i.e. Web 2.0, Web 3.0) and artificial intelligence (AI). A primary focus of cVR is how this transition simultaneously makes use of and augments human capabilities, including psychological, cognitive and social capabilities – especially capabilities linked to a deeper understanding of geometric, temporal and semantic relationships. By extension, cVR further investigates the effects of these changes in human and AI capabilities with respect to a variety of sectors including education, commerce, healthcare, industrial production and others".

IV. DISCUSSIONS

The goal of this section is to study how the above-mentioned concepts are involved in PDT.

Throughout history, human beings have embarked on journeys for countless reasons, ranging from commercial pursuits to recreational activities. With the advent of technological innovations, planning and managing trips have become more convenient and hassle-free. This has been especially true for younger generations, such as Generation Y and Z, who are accustomed to utilizing mobile phones and other digital devices as indispensable instruments in their daily lives.

In the contemporary era, the rapid expansion of online platforms has facilitated swift and convenient access to a wealth of information for individuals. With the advent of these platforms, the process of retrieving data has become immensely expedited, enabling individuals to attain the information they require within a matter of seconds. The availability of online information has revolutionized the way people seek and acquire knowledge, rendering the process more efficient and streamlined. The rapid advancements in technology have transformed people's behaviors and communication habits, leading to the emergence of new patterns studied in the field of cognitive infocommunications.

In today's world, where technology plays a significant role in our lives, tourism providers are faced with the daunting task of keeping up with the constantly evolving needs and preferences of their guests. Recent studies on the travel behaviors of the younger generations, namely Generation Y and Z, have highlighted the importance of catering to individual preferences and providing personalized services to create a memorable and

satisfying travel experience. To meet the requirements of modern-day service providers, the deployment of cutting-edge technologies such as artificial intelligence, virtual reality, and augmented reality can prove to be highly advantageous. These innovative technologies can offer a range of benefits such as increased efficiency, accuracy, and cost-effectiveness. By leveraging the power of artificial intelligence and other advanced technologies, service providers can stay ahead of the curve and maintain a competitive edge in the market.

These findings have led to the development of the concept of personalized digital tourism, which aims to provide tailored experiences to individual travelers. By leveraging these advanced technologies, tourism providers can offer personalized recommendations, customized itineraries, and immersive experiences that cater to the unique preferences and interests of each guest.

A. The Role of Cognitive Infocommunication in the PDT

PDT is motivated by the co-evolution of new generation and digital realities, both at an individual and social level. The distinction between natural and artificial cognitive capabilities is becoming blurred, leading to the development of a Cognitive Entity (CE) model in generation Z research [8]. The CE model is a combination of human and ICT with integrated cognitive capabilities. When analyzing or developing a PDT service, one may base the analysis on the capabilities of CEs instead of isolated cognitive levels of humans and digital systems. This approach provides a higher level of abstraction for the present generation.

B. The Concept of Digital & Cognitive Reality in PDT Research

The PDT is a technology that is utilized through digital services and analysis to create a digital and customer experience-based reality. This technology is implemented in both 2D and 3D environments, as well as in augmented digital environments with digital content management and artificial intelligence in networked settings. As a result, the research of PDT is strongly based on the concepts of IoD. The definition of IoD is as follows [11][12][13][14]:

The term "Reality" has different definitions in literature and plays a crucial role in Personal Digital Tourism (PDT). In this context, the concept of "Internet of Devices" (IoD) defines reality as a set of cognitive capabilities of connected entities (CEs) that work towards a common goal. [15] PDT involves the use of various systems that have both general and specialized CE capabilities. These capabilities ultimately serve the goals of tourism. As a result, this digital and cognitive network can be seen as a digital reality of tourism, which is, in fact, a reality of tourism.

For example, our house has similar equipment to a hotel room or apartment, such as a bed, TV, and bathroom. However, the different quality and integrated set of capabilities of these items highlight the distinct overall purposes of a house versus a hotel room or apartment. Similarly, when we combine artificial cognitive capabilities, such as those provided by AR, VR, XR, 2D, Digital Twin, and AI, with natural cognitive capabilities to serve tourism, we create a digital reality of tourism.

Tourism is a highly significant sector in the service industry that is responsible for providing intangible services. Travelers, however, often desire to experience these services in a more tangible form. To address this desire, the tourism industry has turned to virtual and augmented reality toolkits. These toolkits enable tourists to virtually experience the destinations and services offered by the tourism industry in a more immersive way. By leveraging these technologies, tourism industry professionals can enhance the overall experience of travelers, leading to greater customer satisfaction and loyalty. Additionally, virtual and augmented reality can help businesses in the tourism industry to differentiate themselves from their competitors and attract more customers.

Visual imaging is considered one of the most effective marketing tools for tourism providers who want to create personalized marketing strategies. It allows travelers to experience the location virtually before making a decision to book their trip. Studies have shown that virtual reality (VR) is particularly effective in influencing the decision-making process of travelers [23][24][25].

The AR/VR technology has paved the way for innovative products in the travel and tourism industry. These products are primarily categorized into three segments: AR-powered glasses, AR mobile apps/software, and VR headsets. Among these, the AR mobile apps/software segment is predicted to witness the fastest growth from 2022 to 2027. The augmented reality mobile apps and software market has been expanding rapidly as technology advances, and it is estimated to reach an impressive $4 trillion by the year 2030, which is a significant rise from its 2017 value of $1 trillion [26].

Virtual tourism is a new and exciting trend that is rapidly gaining popularity among smartphone users. It is a type of tourism that allows people to explore different parts of the world without actually having to physically be there. With virtual tourism, people can travel to any corner of the world in real-time, using their smartphones as a portal to a virtual world that is both immersive and interactive. This means that you can explore different cultures, landmarks, and attractions from the comfort of your own home, without ever having to worry about travel costs, jet lag, or any other inconveniences that come with physical travel. Furthermore, virtual tourism is a safe and convenient way to explore the world during times when travel restrictions are in place, making it an ideal alternative for those who still want to satisfy their wanderlust [21].

C. The Role of Generation Theories in the PDT

Generation Theories suggest that the way people from different age groups perceive technology can be considered as a significant generational divide [43]. According to Károly Mannheim, a Hungarian-born sociologist, a generation is not just a group of people born at the same time, but they are also influenced by the common experiences they face during their youth, which have a lasting impact on their social, political, economic, and cultural lives [4]. In 2022, Preethi Lodha conducted a research study to examine the spending habits of different age groups in the United States. The findings of the research indicated that Generation X and Millennials, in

particular, possess considerable purchasing power. However, the research also revealed that the purchasing power of Gen Z is on the rise, with each passing year. These results suggest that the tourism industry can benefit by creating personalized tourism products that cater to the unique demands of these three generations. By doing so, the tourism industry can ensure that the needs of these significant age groups are met while maximizing the economic gains that can be derived from this demographic [5].

The aforementioned theories provide substantial evidence to support the notion that macro-environmental factors play a significant role in shaping the behavioral patterns of different generations, especially in relation to the adoption and usage of technology. These factors may include but are not limited to socio-economic conditions, cultural norms, political climate, and technological advancements.

The field of Sociology has a significant impact on businesses as it helps them understand the needs of their customers and create products and services that effectively cater to those needs. This is especially important in the tourism industry, which is focused on providing services and education to the spending power of generations X, Y, and Z. Digital Tourism is a highly compatible approach with contemporary educational methods and trends. With the assistance of AI (Artificial Intelligence) and digital educational resources, it is now feasible to explore and learn about other countries and continents without the requirement of physical travel. This implies that obtaining direct international experience is no longer restricted by an individual's financial status, rendering it available to everyone during their lifelong learning journey [7]. The acquisition of digital competencies is an indispensable prerequisite for effective participation in modern education. In this regard, the possesion of digital skills is imperative, as it enables individuals to navigate the complex digital environment of modern educational institutions with ease and proficiency. In light of this, individuals pursuing education in contemporary times must invest in developin their digital competencies to optimize their learning outcomes [7].

The interplay between these factors can have a profound impact on how individuals from different generations perceive, interact with, and adopt technology in their personal and professional lives. Therefore, it is essential to consider the macro-environmental factors while devising strategies to cater to the varying needs and preferences of different generations in the context of In 1964, a prominent demographer named William Strauss coined the term "Generation X" to describe the demographic cohort born after the baby boomers and before the millennials.

This generation is generally considered to include those born between the mid-1960s and the early 1980s, and they have had a significant impact on the labor market and society as a whole [18]. The text describes the current generation, which is frequently referred to as Generation Z. The article includes a figure, labeled as Fig. 1, that likely provides additional information about the subject matter [19].

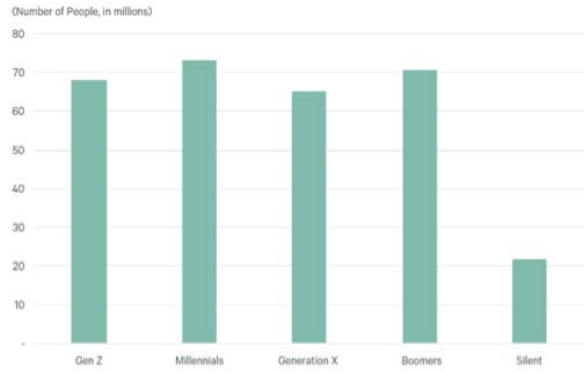


Fig.1. US Population by Generation [20]

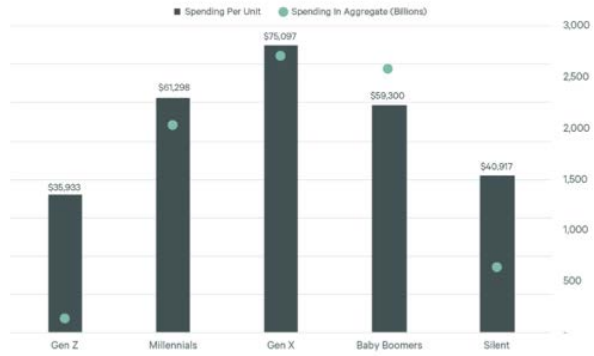


Fig. 2. Spending by Generation [20]

The tables provide information on the importance and purchasing power of Generation Y and Generation Z within the American population. These generations, who are digital natives, are currently the primary users of Personal Digital Technology (PDT).

D. The Role of AÍ Based Data Handling in the PDT

The incorporation of AI-based data handling enables effective processing and analysis of large volumes of data, leading to enhanced decision-making capabilities and improved customer satisfaction. Overall, Personalized Digital Tourism promises to revolutionize the tourism industry by providing tailored and immersive experiences that meet the evolving demands of modern travelers.

To successfully introduce new products and services in the tourism industry, service providers must possess a comprehensive understanding of the continuously evolving needs of their customers. The younger generation, comprising Generation Y and Z, is notably distinct from prior generations, largely due to their exposure to rapid technological advancements. Consequently, they seek personalized products and services that can be conveniently accessed through the Internet. This shift has resulted in the emergence of new behavioral patterns and communication habits that necessitate a thorough understanding of contemporary consumer preferences.

The trend towards Artificial Intelligence (AI) is having a significant impact on the way people communicate and the tourism industry. Face-to-face communication is giving way to digital tools such as Messenger, which has become increasingly popular for problem-solving. The tourism industry is also leveraging AI to collect customer data, which enables them to offer personalized services. In addition, digital reality technology is heavily relied upon to present tourist attractions, hotels, and other destinations. To enhance product customization, tourism service providers are integrating principles from CogInfoCom, Generation theories, DR, and AI. These tools enable providers to tailor their services to meet the unique needs of their customers.

In my paper, I delve into the fascinating world of data handling by artificial intelligence. AI has revolutionized the way we manage data, by taking into account factors such as the quality, accessibility, and security of the data. AI systems are designed to process vast amounts of data using intelligent, interactive algorithms, and to learn from the patterns and characteristics of the data they analyze. The effectiveness of AI is closely tied to recent technological advancements, such as the availability of larger, more accessible data sets, the use of graphical processing units (GPU) for faster processing, the development of intelligent data processing techniques, and the use of application programming interfaces (API) for seamless integration with other systems [29].

Marketing professionals face significant challenges in finding and targeting the right product or service to the right market segment at the right time. However, artificial intelligence (AI) has emerged as a powerful tool that can help service providers to personalize their products and services. By leveraging the power of big data and machine learning algorithms, AI enables service providers to obtain detailed information about their customers, create detailed profiles of each customer, and automatically tailor offers to meet the specific needs of each individual.

AI based data handling: Artificial Intelligence (AI) has emerged as a potent tool that can enable tourism businesses to capture, process, and store massive volumes of data. By harnessing the power of AI, hotels and online travel portals can offer personalized products and services that cater to the unique needs and preferences of their customers, both corporate and leisure. The ability to handle data using AI technology represents a paradigm shift for the tourism industry, empowering businesses to provide a more efficient and bespoke service to their clientele.

AI-based personalization aims to create real-time customer experiences that are targeted to each user's unique needs. With AI-based personalization, companies can generate personalized content, messaging, product and service recommendations, ads, websites, chatbots, and even robots. By tailoring their products and services to the needs and preferences of individual customers, companies can increase customer loyalty, improve customer satisfaction, and ultimately drive revenue growth. AI-based personalization is an essential tool for any business looking to stay ahead of the competition in today's rapidly evolving marketplace [30].

The travel industry has seen a significant transformation, all thanks to the remarkable advancements in Artificial Intelligence (AI). Ensuring successful implementation involves translating advanced AI technology into cognitive functions that can be applied to enhance digital business initiatives within the smart tourism industry [72].

AI has revolutionized the way security is ensured at airports. With the implementation of facial recognition technology, it has become one of the most reliable security solutions for airports. Moreover, this technology has also been adopted by several hotels in China for guest check-ins, making the process much faster and more convenient.

In addition to this, online travel agencies are increasingly using chatbots to assist travelers with their booking process. The chatbot is designed to offer personalized travel recommendations and important information, serving as a versatile tool for travelers seeking advice and guidance.

Chatbots are programmed to answer queries related to flight bookings, accommodation, and other tourist services, providing travelers with prompt and efficient service [73]. This has made the booking process a lot smoother and less time-consuming for travelers. Chatbots-AI is an advanced conversational agent that uses artificial intelligence to engage in intelligent human-like conversations. It is equipped with learning capabilities and can provide personalized services to users [74].

The integration of robots in the hospitality and catering industry is an increasingly pervasive phenomenon. The implementation of artificial intelligence not only facilitates the process of identifying the best value-for-money tourism services for travelers but also aids airlines and hotels in augmenting their revenue streams.

With the deployment of AI-powered robots, hotels, and catering establishments can optimize their operational processes and improve the overall efficiency of their services. The use of such technology in the industry is indicative of the growing trend towards automation and digitization in the service sector.

As AI continues to evolve, its impact on the hospitality and catering industry is set to increase. Businesses in this industry must recognize the benefits of integrating such technology into their operations to remain competitive and provide a superior service to their customers.

Overall, Artificial Intelligence has played a significant role in streamlining and improving various aspects of the tourism industry, making travel more secure, convenient, and efficient for travelers worldwide [31].

V. EXAMPLES

To provide timely assistance to customers, it is important to have a deeply understanding of the latest technologies and trends. This can involve staying up-to-date on advancements in fields such as artificial intelligence, cloud computing, and mobile app development, as well as keeping an eye on emerging market trends and consumer preferences. By staying informed and knowledgeable about these areas, customer service representatives can quickly assess and address customer needs, providing effective solutions that meet their requirements and exceed their expectations. This, in turn, can help to build strong

relationships with customers and establish a reputation for excellence in customer service. This section encompasses real-world illustrations that have not yet attained the status of scientific findings. As a result, the cited literature in this section predominantly comprises practical trade journals.

A. Personalized hotel services

The concept of service personalization entails the practice of tailoring services in a bespoke manner that specifically addresses the unique and individual requirements of each customer. This approach emphasizes the customization of services to ensure that the align with the distinct preferences, needs, and characteristics of individual customers, thereby enhancing their overall experience and satisfaction [65].

The importance of personalized hotel service is evident in three key areas of hotel operations.

(1) The implementation of personalized services at the hotel is aimed at enhancing the quality of customer service and ultimately improving customer satisfaction. Customer loyalty and a competitive edge can be cultivated as a result. The decision of customers to make repeat purchases from a company is contingent upon their satisfaction with the products or services. By ensuring high levels of satisfaction, the hotel can attract repeat business and foster loyal customers, thereby enhancing its competitive advantage.

(2) It's important to create a favorable impression of the hotel. Anticipating the needs of our guests and responding promptly is crucial for establishing a positive image for the hotel. Offering personalized service can make guests feel genuinely cared for and demonstrate that the hotel prioritizes their satisfaction. This approach can help to firmly establish a friendly and considerate image of the hotel in the minds of the public.

(3) Tailoring hotel services to meet individual consumer needs is key to improving customer satisfaction, loyalty, and overall hotel awareness. This, in turn, attracts loyal customers, boosts repeat business, and enhances the hotel's reputation, resulting in increased profits and a larger market share [66].

Due to the growing demand for unique and personalized travel experiences, many large hotel brands have started to merge with various boutique hotel chains. This trend is becoming increasingly popular in the hospitality industry, with many hotel chains recognizing the importance of offering guests a more authentic and personalized experience. One of the most notable examples of this trend is the merger between InterContinental Hotels Group PLC. (IHG) and Kimpton, which has proven to be a successful partnership. By combining their respective strengths and resources, IHG and Kimpton have been able to deliver exceptional service and experiences to their guests, while also expanding their reach and brand recognition in the competitive hotel market [32], after realizing that the habits of Generation Y customers differ from those of previous generations, as they prefer personalized services rather than standardized ones [33].

B. Generation Y guest expectations

In 2017, a survey was conducted by TCI Research on behalf of HOTREC (Hotels, Restaurants, Pubs, and Cafes) to understand the expectations of travelers from hotels and restaurants in the future. The survey was conducted in two parts - the first part examined the opinions of guests who had stayed in European hotels and restaurants, while the second part focused on mapping the expectations of future hotel and restaurant guests.

The survey found that Generation Y (Millennials) have higher expectations from hotels than the previous generations. Apart from the basic requirements of security and privacy, which are important for all generations, Generation Y expects more. They prioritize comfort services that cater to their lifestyle, such as the flexibility to invite their friends to the hotel, access to digital and high-tech entertainment options, and unique design elements that enhance the overall hotel experience. [34]. Millennials, born between 1981 and 1996, have unique preferences and priorities compared to other generations. They value experiences over material possessions and seek out opportunities to explore and try new things. In addition, they are highly tech-savvy and expect businesses and organizations to be up-to-date with the latest technologies. Sustainability is another key factor for millennials, as they are more conscious of their impact on the environment and prefer eco-friendly products and services. Overall, millennials are a dynamic and diverse group with a strong desire for innovation, authenticity, and social responsibility [35].

C. Changing Traveller Report – Gen Z – Cognitive Infocommunication

In 2022, SiteMinder, a leading provider of Australian hotel sales solutions, partnered with Kantar, a renowned market research company, to publish a comprehensive report titled The Changing Traveler Report. The report is based on the responses of over 8,000 travelers from ten countries, including Australia, China, France, Germany, Indonesia, Italy, Spain, Thailand, Great Britain, and the USA. The report aims to map the changes in travel behavior in these countries and identify the factors that influence the decision-making process of modern-day travelers, particularly those belonging to Generation Z.

According to the report, social media plays a critical role in shaping the travel decisions of young travelers. Generation Z relies heavily on online platforms to gather information about their travel destinations, and guest reviews are the primary influencers of their travel choices. The report also highlights that Generation Z prefers to book their trips through various online portals, indicating a shift towards digital platforms for travel booking.

Moreover, the report also reveals that Generation Z has a keen interest in technological advancements in the tourism industry. They are particularly fond of applications such as automated check-in, robots, and artificial intelligence. These technological innovations offer a seamless and hassle-free travel experience to younger travelers, making it a crucial factor in their travel decisions.

Lastly, the report also emphasizes the importance of personalized offers for Generation Z travelers. After completing their trip, younger travelers appreciate it when the tourism service provider approaches them with personalized deals and offers. This tailored approach makes them feel more

valued and appreciated as customers, thereby increasing the likelihood of their return in the future [37].

D. Smart room, Smart hotel – AI in the hospitality industry

Back in 2017, Village Hotels, a UK-based hotel chain, made an exciting announcement. They revealed their plans to install Amazon's famous Echo Dot smart speakers and the Alexa virtual assistant in their hotel rooms. The aim was to provide personalized guest services, allowing guests to conveniently control room functions such as lighting, temperature, and music using only their voice. This move was aimed at making the guests' stay more comfortable and enjoyable, and it was a unique approach to hotel room automation that made Village Hotels stand out from its competitors [38].

In the year 2018, a pioneering four-star smart hotel named KViHotel was launched in the heart of Budapest, becoming the first of its kind in Europe. The hotel has revolutionized the traditional hospitality experience by introducing a smartphone-controlled system, which enables guests to handle various tasks such as check-in, room access, and air conditioning control, all through their mobile devices. This innovative approach has eliminated the need for physical keys, providing guests with a seamless and convenient way to manage their stay [39].

E. AR &VR in the hospitality industry

1) AR

In the tourism sector, it's crucial for destinations to tailor their offerings to remain competitive and attractive to visitors. An effective method to achieve this is through the implementation of Augmented Reality (AR). AR can enrich the tourist experience by delivering interactive and immersive content that enhances the value of their visit [68].

The use of augmented reality applications in the tourism industry by various businesses such as hotels, tour operators, restaurants, and museums is poised to intensify competition and drive research into enhancements to improve tourist services. This trend will provide tourists with new and immersive experiences through a variety of services. Recognizing tourism activities as both an experience and a necessity will help ensure the continued travel of tourists [69].

Starwood Hotels and Resorts Worldwide, Inc. was a multinational hospitality company that owned, operated, franchised, and managed a vast portfolio of hotels, resorts, spas, residences, and vacation rental properties across the globe. The company was founded in 1969, and at its peak, it operated over 1,200 properties in nearly 100 countries.

In 2016, Marriott International acquired Starwood Hotels and Resorts Worldwide, Inc. in a merger deal worth $13 billion, which made Marriott the largest hotel chain in the world.

One of the unique features of Starwood Hotels and Resorts was their use of beacon technology, which allowed guests to receive virtual keys on their mobile phones. The virtual keys enabled guests to open their hotel room doors without having to visit the front desk, thus reducing wait times and improving convenience. This technology was a significant innovation in the hospitality industry and helped elevate Starwood Hotels and Resorts to become one of the most innovative and customer-focused brands in the world [39].

2) VR

Over the previous twenty years, there has been a notable surge in the adoption of information and communication technologies with diverse attributes aimed at generating value and offering distinct services. These technologies have significantly contributed to enriching the overall experiences of travelers throughout their journeys [69].

The implementation of virtual reality (VR) technology can provide tourists with an innovative way to engage with their travel experiences. By immersing users in interactive and simulated environments, VR has the potential to enhance engagement and enable tourists to co-create unique and personalized experiences [70].

Travelers have the ability to view hotel options, gather information, find their way around different locations, and discover points of interest and amenities through their mobile devices, allowing them to customize their travel experiences [71].

Using virtual reality (VR) is an incredibly effective way to capture the attention and interest of potential tourists in a particular destination, hotel, or attraction. For example, one could immerse themselves in a 360-degree virtual tour of Hamilton Island with Quantas, which is even better experienced with VR glasses or Google Cardboard. Similarly, one could use the Atlantis Dubai Virtual tool to get an idea of what a hotel has to offer before booking a stay there. VR allows people to experience a destination, hotel, or attraction in a way that is both informative and engaging, making it an invaluable tool for the tourism industry [40][41][42].

VI. CONCLUSIONS

In the contemporary era, technology has become a predominant macro-environmental factor, significantly reshaping human lifestyles. And throughout personality development, a child's persona undergoes continuous evolution, ultimately shaping the character traits observed in adulthood.

The tourism and other service industries have undergone rapid transformation as a result of technological advancements. The continuous evolution of technology has not only impacted human behavior and communication but has also led to an increasing demand for personalized services.

The solution lies in leveraging cutting-edge technologies like AI, virtual reality, and augmented reality to deliver customized experiences.

The tourism industry is experiencing increasing demand for personalized services, which has given rise to the development of Personalized Digital Tourism (PDT). PDT incorporates various technical elements such as Cognitive Infocommunications, Generation theories, Digital Realities, and AI-based data handling. By harnessing these technical elements, tourism service providers can more effectively customize their offerings to meet each customer's distinct preferences and requirements.

PDT delivers a distinct and personalized experience to each customer, guaranteeing that their preferences and needs are fulfilled. This concept has already been successfully implemented in the tourism industry, yielding favorable

outcomes. In the upcoming years, it is anticipated that PDT will assume a pivotal role in supporting both industry practitioners in the tourism sector and scholars within related fields.

References

[1] *Mindennapi Pszichológia Lexikon*. Available: https://mipszi.hu/lexikon/k?page=1, Accessed on: May 14, 2023.

[2] N. A. Stillings, C. H. Chase, S. E. Weisler, M. H. Feinstein, and E. L. Rissland, "Cognitive science: An introduction", *MIT press*, 1995.

[3] J. L. Bermúdez, "Cognitive science: An introduction to the science of the mind", *Cambridge University Press*, 2014.

[4] M. Háver-Varga, "Miért kritikusak a fiatalok az idősekkel, és az idősek miért nem figyelnek a fiatalokra? – Tükröt tart nekünk a generációkutató", April 2023. Available: https://kepmas.hu/hu/rejtelyes-z-generacio-egyuttmukodes-mai-tizen-es-huszonevesekkel-bereczki-eniko-generaciokutato-alfa, Accessed on: May 14, 2023.

[5] P. Lotha, "How American spend their money by age group", In: *World Economic Forum*, 2022. https://www.weforum.org/agenda/2022/10/americans-spend-their-money-by-generation/ Accessed on: August 13, 2023.

[6] Muskan, "7 applications augmented reality hospitality industry", July 2021. https://www.analyticssteps.com/blogs/7-applications-augmented-reality-hospitality-industry, Accessed on: May 13, 2023.

[7] B. G. Kálmán, "Új kompetenciák és élethosszig tartó tanulási kultúrák az ipar 4.0 számára", MA thesis, New competences and lifelong learning cultures for Industry 4.0, in Hungarian, 2021. https://repozitorium.omikk.bme.hu/handle/10890/18207 Downloaded 2023.08.14.

[8] T. Juhász, B. G. Kálmán, A. Tóth, and A. Horváth, "Digital Competence in the Visegrád Countries", *Digital Competence Development in a Few Countries of the European Union, Management and Marketing*, vol. 17, no. 2, 2022, pp. 178–192. DOI: 10.2478/mmcks-2022-0010

[9] Baranyi, Péter Zoltán and Berki, Borbála and Csapó, Ádám B. (2024) *Concepts of Cognitive Infocommunications*. *Infocommunications Journal*, 16 (Specia). pp. 37–48. ISSN 2061-2079

[10] P. Baranyi, A. Csapo, and Gy. Sallai: „*Cognitive Infocommunications (CogInfoCom)"*, Springer International Publishing Switzerland, 2015, p. 191. 978-3-319-19607-7, 978-3-319-19608-4 eBook, DOI: 10.1007/978-3-319-19608-4, http://www.springer.com/us/book/9783319196077#aboutBook

[11] J. A. Madisyn, "Cognitive science, Cognitin, Human Brain", *Plick Press*, 2012, ISBN: 978-613-6-27438-6.

[12] A. Csapó, and P. Baranyi: „CogInfoCom Channels and Related Definitions Revisted", *IEEE 10th Jubilee International Symposium on Intelligent Systems and Informatics (SISY 2012)*, September 20-22, 2012, Subotica, Serbia, pp. 73–78. (978-1-4673-4750-1/12)

[13] P. Baranyi, A. Csapo, and P. Várlaki, „An Overview of Research Trends in CogInfoCom", in *IEEE 18th International Conference on Intelligent Engineering Systems, (INES 2014)*, July 3-5, 2014, Tihany, Hungary, pp. 181–186. (978-1-4799-4616-7)

[14] P. Baranyi, and A. Csapo, „Revisiting the concept of generation CE – Generation of Cognitive Entities", *6th IEEE International Conference on Cognitive Infocommunications (CogInfoCom 2015)*, October 19-21, 2015, Győr, Hungary, pp. 583–586. (978-1-4673-8129-1)

[15] P. Baranyi, Á. Csapó, T. Budai, and G. Wersényi, "Introducing the Concept of Internet of Digital Reality–Part I.", *Acta Polytechnica Hungarica*, vol. 18, no. 7. 2021, pp. 225–240.

[16] G. Wersényi, Á. Csapó, T. Budai, and P. Baranyi, "Internet of Digital Reality: Infrastructural Background–Part II.", *Acta Polytechnica Hungarica,* vol. 18, no. 8, 2021, pp. 91–104.

[17] K. Manheim, "Das Problem der Generationen", In *P. Kecskemeti (ed.), Essays on the Sociology of Knowledge: Collected Works*, vol. 5, New York, Routledge, pp. 276–322.

[18] W. Strauss, N. Howe, "Generations", *Quill, William Morrow*, New York, US, 1992, p. 16.

[19] D. M. McGregor, "The Human Side of Enterprise", *McGrawHill*, 2006, pp. 43–82.

[20] B. Horowitz, "After Gen X, Millenials, what should next generation be?", *USA today*, 2012. Available: https://abcnews.go.com/Business/gen-millennials-generation/story?id=16275187, Accessed on: August 13, 2023.

[21] A. Wang, "How Does Online Spending Vary By Generation?", 2022, Available: https://www.cbre.com/insights/articles/omnichannel-how-does-online-spending-vary-by-generation

[22] M. Heim, "The Metaphpysics of Virtual Reality", *Oxford University Press*, New York, 1993, pp. 109-128.

[23] P. Baranyi, "Special Issue on Internet of Digital and Cognitive Reality: Applications and Key Challenges", *Special Issue of the Infocommunication Journal, Special Issue: Internet Of Digital & Cognitive Realities*, pp. 1–1; 2023.

[24] A. Aziz, and N.A. Zainol, "Destination image: an overview and summary of selected research (1974-2008)", *International Journal of Leisure and Tourism Marketing*, vol. 2, no. 1, 2011, pp. 39–55.

[25] A. Pestek and M. Sarvan, "Virtual Reality and Modern Tourism", *Journal of Tourism Futures*, vol. 7, no. 2, 2021, pp. 245–250.

[26] S. Verma, L. Warrier, B. Bolia, and S. Mehta, "Past, Present and Future of virtual tourism – a literature review", *International Journal of Information Data Management Insight*, vol. 2, no. 2, November 2022.

[27] Global Market Estimates, "AR/VR in Travel & Tourism Market size", *Market Report*, 2023. Available: https://www.globalmarketestimates.com/market-report/ar-vr-in-travel-tourism-market-3708 Accessed on: 2023.05.13

[28] J. Copeland, "What is Artificial Intelligence?", *Alanturning.net*, 2000 May, Available: http://www.alanturing.net/turing_archive/pages/Reference%20Articles/What%20is%20AI.html, Accessed on: May 14, 2023.

[29] M. I. Jordan, and S. Russell, "Computational Intelligence", In: R.A. Wilson and F.C. Keil (Eds.), *The MIT Encyclopedia of the cognitive sciences (MITECS)*, MIT press, 2001, p. 75.

[30] CSU Global, "How does AI actually work?", August 2021. Available: https://csuglobal.edu/blog/how-does-ai-actually-work

[31] K. Walch, "8 Exampples of AI peronalization across industries", November 2020. Available: https://www.techtarget.com/searchenterpriseai/feature/8-examples-of-AI-personalization-across-industries Accessed on: May 14, 2023.

[32] O. Izchak, "6 examples of how AI is used in the trale industry", 2022. Available: https://www.hotelmize.com/blog/6-examples-of-how-ai-is-used-in-the-travel-industry/ Accessed on: May 14, 2023.

[33] IHG agrees to acquire kimpton hotels, restaurants to create the worlds largest boutique hotels, 2014. Avaliable: https://www.ihgplc.com/en/news-and-media/news-releases/2014/ihg-agrees-to-acquire-kimpton-hotels--restaurants-to-create-the-worlds-largest-boutique-hotel-busine, Accessed on: May 10, 2023.

[34] Ma már csak ilyen szállodába megy az Y generáció, Available: http://kamaraonline.hu/cikk/ma-mar-csak-ilyen-szallodaba-megy-az-y-generacio, Accessed on: May 10, 2023.

[35] Hotrec EU Newsroom: Study Hotrec & TCI research, 2017, Available: https://www.hotrec.eu/policy/tci-research-study-mapping-the-future-of-hotel-and-restaurant-experience/, Accessed on: August 14, 2023.

[36] How Millennials are steadily impacting the hotel, foodservice, and hospitality industries, Available: https://www.kent.edu/ehhs/fla/hm/millennial-generation, Accessed on: May 10, 2023.

[37] J. Trillsam, "Reiseverhalten den jungen Generation", 2022. Available: https://www.tip-online.at/news/51357/siteminder-studie-reiseverhalten-der-jungen-generation, Accessed on: May 21, 2024.

[38] P. Davis, "Amazon alexa checks in uk hotel industry first", 2017. Available: https://travelweekly.co.uk/articles/281393/amazon-alexa-checks-in-to-village-in-uk-hotel-industry-first, Accessed on: May 12, 2023.

[39] V. Langbein, "Aludtunk egyet Európa első okosszállodájában", hsw.hu, 2018. Available: https://www.hwsw.hu/hirek/58598/kvihotel-proptech-kiprobaltuk-okosszalloda.html, Accessed on: May 12, 2023.

[40] Hospitalitytech, "How hotels are using beacons and augmented reality", 2015. Available: https://hospitalitytech.com/how-hotels-are-using-beacons-and-augmented-reality, Accessed on: May 12, 2023.

[41] Muskan, "7 applications augmented reality hospitality industry", July 2021. Available: https://www.analyticssteps.com/blogs/7-applications-augmented-reality-hospitality-industry, Accessed on: May 13, 2023.

[42] Revfine, "How VR can Enrich the Hospitality Industry", 2020. Available: https://www.revfine.com/virtual-reality-hospitality-industry/ Accessed on: May 13, 2023.

[43] A. Tóth, T. Juhász, and B. G. Kálmán, "Revfine, Determining factors of motivational dimensions". *Acta Polytechnica Hungarica* 1785-8860 1785-8860, 19 (4), pp. 229–250 2022 Accessed on: Februar 6, 2024.

[44] M. Zöldy, and P. Baranyi, "Cognitive Mobility–CogMob," *12th IEEE International Conference on Cognitive Infocommunications (CogInfoCom 2021)*. Proceedings IEEE, pp. 921–925.

[45] Á. B. Csapó, I. Horváth, P. Galambos, and P. Baranyi, "VR as a Medium of Communication: from Memory Palaces to Comprehensive Memory Management," *2018 9th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, Budapest, Hungary, 2018, pp. 000 389–000 394, DOI: 10.1109/CogInfoCom.2018.8639896.

[46] Á. B. Csapó, A. Sudár, B. Berki, B. Gergely, B. Berényi, and C. Czabán, "A test space for virtual rotation measurement in MaxWhere," *2020 11th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, Mariehamn, Finland, 2020, pp. 000 585–000 586, DOI: 10.1109/CogInfoCom50765.2020.9237865.

[47] Á. B. Csapó, A. Sudár, B. Berki, B. Gergely, B. Berényi, and C. Czabán, "Measuring Virtual Rotation Skills in MaxWhere," *2020 11th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, Mariehamn, Finland, 2020, pp. 000 587–000 590, DOI: 10.1109/CogInfoCom50765.2020.9237889.

[48] T. Setti, and Á. B. Csapó, "Cognitive Aspects of 2D Content Integration and Management in 3D Virtual Reality Spaces," *Infocommunications Journal*, 2023, 15(Specia), pp. 37–45.

[49] A. Sudár, and Á. B. Csapó, "Interaction Patterns of Spatial Navigation in VR Workspaces," *2019 10th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, Naples, Italy, 2019, pp. 615–618, DOI: 10.1109/CogInfoCom47531.2019.9089998.

[50] A. Sudár and Á. B. Csapó, "Descriptive Markers for the Cognitive Profiling of Desktop 3D Spaces," *Electronics*, 2023, 12(2), 448.

[51] A. Sudár, and Á. B. Csapó, "Elicitation of Content Layout Preferences in Virtual 3D Spaces Based on a Free Layout Creation Task," *Electronics*, 2023, 12(9), 2078.

[52] A. Kő, I. Szabó, Á. B. Csapó, T. Kovács, L. Lőrincz, and P. Baranyi, "Digital & cognitive corporate reality," *Infocommunications Journal*, 2023, 15(Specia), pp. 2–10.

[53] A. Sudár and Á. B. Csapó, "Interaction Patterns of Spatial Navigation and Smartboard Use in VR Workspaces," Klempous, R., Nikodem, J., Baranyi, P. Z. (eds) Accentuated Innovations in *Cognitive Info-Communication. Topics in Intelligent Engineering and Informatics*, vol 16. Springer, Cham. DOI: 10.1007/978-3-031-10956-0_7

[54] B. Berki, "Level of Presence in MaxWhere Virtual Reality," *11th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, Mariehamn, Finland, 2020, pp. 000 485–000 490, DOI: 10.1109/CogInfoCom50765.2020.9237826.

[55] I. Horváth, and B. Berki, "Unlocking the Potential of Immersive VR Systems: The Role of Gesture and Natural Controls," *2023 IEEE 2nd International Conference on Cognitive Aspects of Virtual Reality (CVR)*, Veszprém, Hungary, 2023, pp. 000 093–000 098, DOI: 10.1109/CVR58941.2023.10394795.

[56] I. Horváth, and B. Berki, "Investigating the Operational Complexity of Digital Workflows Based on Human Cognitive Aspects," *Electronics*, vol. 12, no. 3, p. 528, 2023. DOI: 10.3390/electronics12030528.

[57] B. Berki, "Role of Presence, Memory and Spatial Ability in a Desktop Virtual Reality," in R. Klempous, J. Nikodem, and P. Z. Baranyi (Eds.), Accentuated Innovations in Cognitive Info-Communication, Topics in *Intelligent Engineering and Informatics*, vol. 16. Cham: Springer, 2023, DOI: 10.1007/978-3-031-10956-0_4.

[58] I. Horváth, Á. B. Csapó, B. Berki, A. Sudár, and P. Baranyi, "Definition, Background and Research Perspectives Behind 'Cognitive Aspects of Virtual Reality' (cVR)," *Infocommunications Journal, Special Issue: Internet of Digital & Cognitive Realities*, pp. 9–14, 2023. DOI: 10.36244/ICJ.2023.SI-IODCR.2.

[59] I. Horváth, "Experiences and Guidelines for Developing 3D VR Curricula," Klempous, R., Nikodem, J., Baranyi, P. Z. (eds) Accentuated Innovations in Cognitive Info-Communication. Topics in *Intelligent Engineering and Informatics*, vol 16. Springer, Cham, 2023. DOI: 10.1007/978-3-031-10956-0_5

[60] I. Horváth, and Á. B. Csapó, "Motivations and Tools Relevant to Personalized Workspaces in VR Environments," *Electronics* 2023, 12, 2059. DOI: 10.3390/electronics12092059

[61] I. Horváth, "The 4th dimension of personalization in VR," *2022 1st IEEE International Conference on Cognitive Aspects of Virtual Reality (CVR)*, Budapest, Hungary, 2022, pp. 000 085–000 088, DOI: 10.1109/CVR55417.2022.9967573.

[62] I. Horváth, "Personalized learning opportunity in 3D VR," *2020 11th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, Mariehamn, Finland, 2020, pp. 000 425–000 430, DOI: 10.1109/CogInfoCom50765.2020.9237895.

[63] I. Horváth, "The Edu-Coaching Method in the Service of Efficient Teaching of Disruptive Technologies", *Cognitive Infocommunications Theory and Applications*, Springer e-book 2018. ISSN 2193-942X, ISBN 978-3-319-95996-2

[64] J. Lanier, "Virtual reality: The promise of the future," *Interactive Learning International*, 19912, 8(4), pp. 275–79.

[65] D. Ball, P. S. Coelho, and M. J. Vilares, "Service Perssonalization and loyalty", *Journal of Services Marketing*, 200620391-403. DOI: 10.1108/08876040610691284

[66] Y. Zhang, "Research on Hotel Industry Personalized Service from the Perspective of Experience Economy", January 2018: *Conference Asia-Pacific Social Science and Modern Educations Conference (SSSME 2018)*, DOI: 10.2991/ssme-18.2018.21, License, CC BY-NC 4.0 https://www.researchgate.net/publication/327736474_Research_on_Hotel_Industry_Personalized_Service_from_the_Perspective_of_Experience_Economy

[67] D. I. Han, T. Jung, and A. Gibson, "Dublin, AR: Implementing Augmented Reality (AR) in Tourism", In Z. Xiang, and I. Tussyadiah (Eds), *Information and Communication Technologies in Tourism* (511–523). Springer Computer Science: New York, 2013.

[68] E. Ozkul, and S. T. Kumlu, "Augmented Reality Applications in Tourism", December 2019, *International Journal of Contemporary Tourism Research* 2, pp. 107–122, DOI: 10.30625/ijctr.625192

[69] W. Wei, "Research progress on virtual reality (VR) and augmented reality (AR) in tourism and hospitality", *J. Hosp. Tour. Technol.*, 10 (4) (2019), pp. 539–570, DOI: 10.1108/jhtt-04-2018-0030

[70] A. Yuan, and J. Hong, "Impacts of Virtual Reality on Tourism Experience and Behavioral Intentions: Moderating Role of Novelty Seeking", 2023, May 11, DOI: 10.1177/10963480231171301

[71] D. Buhalis, M. S. Lin, and D. Leung, "Metaverse as a driver for customer experience and value co-creation: Implications for hospitality and tourism management and marketing", *In J. Contemp. Hosp. Manag.*, 35 (2) (2022), pp. 701–716, DOI: 10.1108/ijchm-05-2022-0631

[72] C. C. Hsu, "Artificial intelligence in smart tourism: A conceptual framework". In *Proceedings of The 18th International Conference on Electronic Business* (pp. 124–133). ICEB, Guilin, China, December 2-6, 2018.

[73] S. Palahan, and S. Arunthari, "Innovating Tourism: Personalized Recommendations through AI", CVIPPR '24: *Proceedings of the 2024 2nd Asia Conference on Computer Vision, Image Processing and Pattern Recognition*, April 2024, Article No.: 13, Pages 1–5, DOI: 10.1145/3663976.3663991

[74] A. O. Ikumoro, and M. S. Jawad, "Assessing Intelligence Conversation Agent Trends-Chatbots-AI Technology Application for Personalized Marketing", *TEST: Engineering&Management*, Vol.81., November-December 2019, ISSN: 0193-4120 Page No. 4779 - 478

Judit Grotte, PhD habil., College Professor, possesses over 10 years of domestic and international professional experience in the hotel and travel agency sectors. She has lived in Austria, the Netherlands, and the United States. Alongside her tourism career, she has been teaching in higher education since 1997 in both Hungarian and English. She has been invited to teach at prestigious Hungarian institutions such as Budapest Metropolitan University, where she created and led the International Hotel Specialization for the Tourism and Hospitality BA program in both Hungarian and English. At Sopron University, she not only teaches but also supervises doctoral research in tourism. Other institutions where she has taught include Budapest Business School, Budapest University of Technology and Economics, and Corvinus University of Budapest. Her teaching contributions extend to international universities, most notably Coventry University in England, and ESSCA in France. She has been invited multiple times as a Keynote Speaker at international conferences and has undertaken roles such as section chair and conference organizer. Moreover, she is a member of the editorial boards of two international journals, performs peer review duties, and is dedicated to supporting students' scientific activities.

The Use of Design Thinking Methodology in the Design and Development of an Interactive Web-based Personalized Trip Planning Tool: A Case Study of Thailand

Tiparpa Soongswang, Kawin Srisilpavongse, Kritawat Kraiwitchaocharoen, Kiartnarin Udomlapsakul, Nuttayos Charukulvanich, Kritchavit Thippayajindakul, Nattakit Pisitsup, Burapa Chinwatanakit, Maia Kawamura, Mathis Person, Napatra Navanugraha, Tai Tienboon, Natdanai Aramrueng, Chawin Sungkhapong, Gevalin Wongweerakit, and Aung Pyae*

***Abstract*—Thailand's economy relies heavily on tourism, drawing millions of visitors from around the globe. Despite the advances in e-tourism facilitated by internet technologies, existing platforms often fall short in fully representing Thailand's diverse attractions and frequently overlook local businesses, adversely affecting tourists' planning experiences. To tackle these challenges, we developed "Nimbus," an innovative web application created using design thinking methodology. Nimbus offers personalized trip plans generated by a machine learning algorithm that caters to user preferences and highlights both prominent and hidden local destinations. Utilizing cloud computing, a RESTful API, Next.js, and Flask, Nimbus provides scalable, server-side rendered interactions. This study underscores Nimbus as a transformative tool for enhancing Thailand's e-tourism by promoting local economies and has the potential to revolutionize global e-tourism practices. Usability testing affirms that Nimbus is effective and complies with established UI/UX guidelines, positioning it as a valuable tool for showcasing unique destinations worldwide. The results also validate design thinking as an effective approach for e-tourism, demonstrate the applicability of existing UX laws in designing e-tourism systems, and underscore the utility of the System Usability Scale (SUS) in evaluating such systems. This research paves the way for further exploration of design thinking in e-tourism, the implementation of advanced web technologies, and the relevance of SUS in assessing system usability.**

***Index Terms*—human-computer interaction, tourism, design thinking, software engineering**

I. Introduction

When people decide to travel, they must select a destination, sometimes while browsing through an overabundance of travel guides, cruise marketing, and alluring package deals, whether online or offline [45]. Renowned for its picturesque landscapes, rich culture, and history, Thailand has long been a prominent tourist destination among international travelers in South-East Asia and the world [20]. According to the Tourism Authority of Thailand [37], Thailand has consistently secured a prime position in numerous global tourism rankings in the past decade. The Ministry of Tourism and Sports Thailand also states that Thailand's tourism significantly bolstered the nation's economy, contributing 11.8% to the GDP in 2019. According to [30], Thailand's economy relies heavily on the tourism industry, which proved its resilience during the 2008 economic downturn when the tourism sector played a crucial role in driving the economy, creating numerous jobs, and minimizing the impact of the crisis. However, the global COVID-19 pandemic, which started in early 2020, severely impacted Thailand's tourism sector with stricter international travel regulations and border controls, significantly reducing international tourist arrivals between early 2020 and mid-2022 [26].

Consequently, tourism's contribution to Thailand's GDP significantly dropped to just 1% in 2021, and the number of foreign visitors plummeted from 39.8 million in 2019 to a mere 0.43 million in 2021 [35]. A significant decline in international tourist arrivals due to travel restrictions and fear of COVID-19 transmission led to a massive revenue loss in Thailand's tourism sector [1]. As the number of international tourists decreased in the wake of the pandemic, the country suffered a significant loss of revenue, which had a profound impact on businesses nationwide, including hotels, restaurants, and airlines that were particularly hard-hit, as they faced a substantial decrease in income [36], furthermore, as a direct consequence of this significant loss, the travel and tourism industry alone in Thailand experienced a staggering reduction of approximately 1.33 million jobs in 2021 [19].

These drastic changes underscore the pandemic's impact on Thailand's tourism industry, highlighting the need for developing resilient and sustainable strategies, such as promoting domestic tourism, attracting digital nomads, and ensuring sustainable tourism practices to secure and sustain the future of the tourism sector of Thailand. In 2019, although the number of domestic tourists in Thailand, which amounted to 34.8 million, exceeded that of international tourists, who numbered 61.6 million, the economic contributions made by the international tourists surpassed those of the local travelers [35]. This data clearly illustrates international tourism's significant role in boosting the country's economy. Also, the TAT had projected a considerable resurgence in tourism,

International School of Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand. E-mail: Tiparpa Soongswang (Tiplooknam@gmail.com), Kawin Srisilpavongse (KawinSrisilpavongse503@gmail.com), Kritawat Kraiwitchaocharoen (kritawat.kra@gmail.com), Kiartnarin Udomlapsakul (wish.kudomlap@gmail.com), Nuttayos Charukulvanich (nuttayos.c@gmail.com), Burapa Chinwatanakit (burapachi9@gmail.com), Napatra Navanugraha (pipp432@gmail.com), Chawin Sungkhapong (chawin.sung@gmail.com), Kritchavit Thippayajindakul, Nattakit Pisitsup, Maia Kawamura, Mathis Person, Tai Tienboon, Natdanai Aramrueng, Gevalin Wongweerakit (nimbus.ISE@gmail.com)

* International School of Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand (e-mail: aung.p@chula.ac.th)

DOI: 10.36244/ICJ.2025.6.9

forecasting approximately 25 million foreign tourists once COVID-19 restrictions were eased and lifted and the country reopened. This projection signified a more than twofold increase from the 11.81 million visitors recorded in 2022. Despite this encouraging growth, the anticipated numbers are still considerably lower than the peak of 39.8 million tourists Thailand welcomed in the pre-pandemic year of 2019[7]. Unlike the steady growth trends observed before the pandemic, several notable shifts have occurred in the nation's tourism market post-pandemic. Given these dynamics, Thailand must closely monitor and swiftly adapt to emerging tourist trends. Embracing these transformations will be essential for attaining and potentially exceeding the pinnacle of the country's tourism sector witnessed in 2019.

Advances in information technology have revolutionized the tourism sector, replacing traditional paper-based reservations with online bookings and databases, enhancing client-service communication, and elevating accessibility, mobility, and personalization through emerging technologies such as Virtual Reality (VR) and Artificial Intelligence (AI) [10]. This technological adoption has simplified travel procedures, ensured reliable information, and enabled safer, touch-free payment and booking systems, especially crucial during and after the COVID-19 pandemic [5]. For instance, in the existing study [8], the researcher analyzed an interactive webcam live-streaming campaign by a wildlife tourism operator during COVID-19 lockdowns, finding that such virtual tourism can promote tourism recovery and conservation action and serve as a cost-effective strategy for audience engagement during crises. Thailand's tourism industry, like others, is significantly influenced by these technological advancements. Such emerging technologies are also promising to promote Thailand's tourism and hospitality industry in the post-COVID-19 era. For instance, the study [25], states that since the GPT-3 prototype's launch in 2022, the conversational system ChatGPT has sparked immense interest, promising to revolutionize digital transformation, albeit with certain risks; the researchers introduce ChatGPT and offers preliminary guidelines for its use in the tourism sector.

Despite its transformative potential, information technology in tourism still faces significant challenges, particularly in web and mobile applications for e-tourism, including limitations such as lack of multifunctionality, personalization, and real-time data updates that can negatively impact user satisfaction. According to the Economist Intelligence Unit [13], Thailand must prepare for the requirements of tech-savvy young travelers, digital nomads, and remote workers visiting the country. Although the Thai tourism industry has adopted various technologies like online booking websites, digital advertising for tourism businesses, and smart devices in hospitality businesses, it has yet to develop a proprietary technology or tool for generating personalized trip schedules that cater to its tourists' preferences. Although Thailand is renounced for its popular tourist destinations, including beaches and ancient temples, there are many lesser-known locales nationwide, such as national parks in the north, Bangkok's Chinatown, and Phuket's Old Town, which also hold unique appeal. Due to inadequate promotional efforts, these hidden gems remain underutilized, confining the growth potential of the local tourism industry. This restricted range of suggested tourist sites impedes broader tourist distribution, causing some areas to miss out on higher visitor numbers. It's worth mentioning that, according to the authors' best knowledge, a digital platform currently does not exist to highlight lesser-known or undiscovered destinations within Thailand.

Furthermore, the COVID-19 pandemic has significantly impacted local and small-to-medium enterprises within the country, pushing many to the brink of bankruptcy. According to the United Nations [38], extant research indicates that these businesses must recover quickly. Hence, Thailand's authorities need to boost local businesses while attracting more local and international travelers to Thailand. Therefore, Thailand's leaders must implement effective digital strategies that rejuvenate local companies and entice more domestic and international travelers to the Kingdom. This could potentially involve enhancing the country's e-tourism infrastructure, such as online tourism platforms for better global reach, providing incentives for local tourism, promoting sustainable tourism practices, or spotlighting unique cultural and natural assets that make Thailand a compelling destination.

In response to the abovementioned challenges, this study presents "Nimbus," an interactive personalized trip planning tool harnessing cloud computing and application programming interface technologies. Using the 'design thinking' methodology, 'NimBus' is designed to streamline the trip planning experiences of travelers to Thailand and to spotlight lesser-known Thai destinations. This is accomplished through a machine learning algorithm that matches travelers' preferences with a wide range of suggested destinations across the country. The tool's algorithm further crafts a tailored itinerary based on various factors like a traveler's interests, constraints, preferred location types, operational hours, travel times, and transportation methods. The main goal of 'Nimbus' is to boost local businesses in Thailand, thus fostering a sustainable business ecosystem for travelers and business owners. This project's key contributions encompass the UX/UI of tourist destination recommendations, aiming to enhance and elevate visitors' experience in Thailand and stimulate the local economy through user-centric technology. This study's findings can help Thai authorities and IT researchers enhance tourism experiences in Thailand using emerging information technologies. This study aims to achieve the following objectives:

- To engineer a user-centered travel planning platform named 'NimBus' tailored to the unique needs of both international and local tourists in Thailand,
- To evaluate the usability and user experience offered by the 'NimBus' application, understanding the ease of its use and the overall satisfaction of its users,
- To understand the suitability of design thinking methodology in designing and developing the 'NimBus' application,
- To examine the practical feasibility of 'NimBus' within Thailand's dynamic tourism industry, determining its potential impact and effectiveness in real-world settings.

- To advocate for the broader implementation of Information and Communication Technology (ICT) applications within the Thai tourism sector as a catalyst for future growth and advancement.

The paper details 'Nimbus,' a personalized trip planning tool for tourists in Thailand, incorporating innovative approaches to e-tourism. It uses design thinking methodology to enhance empathy, iterative design, and real-world usability, diverging from traditional digital tourism tools. Nimbus employs a sophisticated algorithm that customizes itineraries based on user preferences, local insights, and real-time constraints like operational hours and transport options, promoting both well-known and lesser-visited sites. By spotlighting lesser-known attractions and local businesses, Nimbus not only supports local economies but also encourages tourist traffic distribution. The scalability of Nimbus is explored, indicating potential adaptations to other regions, enhancing its global applicability and contributing to the fields of Human-Computer Interaction (HCI) and tourism.

II. Literature Review

Although Thailand experienced a more significant influx of domestic tourists in 2019, the country's economy significantly benefited from international tourism, with a staggering 61.6 million international tourists compared to 34.8 million local travelers [37]. Of these international tourists, China was Thailand's most significant tourism source before the pandemic [37]. However, with the extension of China's zero-covid policy until 2023, Thailand must reduce its reliance on this specific market and diversify its target customers for the tourism and hospitality industry [32]. Consequently, there has been a decline in tourists from China compared to the numbers seen in 2019 [13]. During the reopening phase, the top visitors to Thailand are from the US, Germany, the UK, Japan, and South Korea, respectively [35]. Additionally, tourist arrivals from ASEAN, Europe, and the US have increased from January to August 2022. These statistics allow the Tourism Authority of Thailand (TAT) to diversify the country's tourism market and focus on new target groups, particularly visitors with higher average expenditure per person, such as Americans or Europeans [37].

Thanks to integrating information and communication technologies (ICTs) in the tourism sector, the convenience of visitors' experiences (e.g., trip planning) has significantly progressed over the past decade. Innovative tourist activities that can modify conventional experiences and give rise to fresh tourism experiences have been made possible by the ongoing development of new technology [27]. The current state of the tourist industry in Thailand and worldwide has been profoundly altered by revolutionary advances in information technology, resulting in the emergence of Ambient Intelligence (AmI) tourists, a customized, seamless travel experience utilizing technology [9]. One significant transformation is the shift from traditional cash transactions to modern cashless payment systems. Another step toward improving operational efficiency is the replacement of paper-based reservation methods with online booking and extensive booking databases. Additionally, the development and widespread use of the Internet has altered how people seek and communicate information online, considerably facilitating interactions between visitors and service providers. The body of extant research highlights the crucial part that ICTs have played in transforming the travel and tourism sector, improving the overall traveler experience, and streamlining several corporate procedures.

In recent years, the tourism industry of many countries has integrated emerging technologies to enhance services [5]. According to [28], the researcher discusses the effects of the digital revolution on tourism, focusing on "Tourism 4.0" and "Smart Tourism" shaped by Industry 4.0 and IoT. Furthermore, the study dissects the impacts on the industry, differentiating between the two tourism models and how digital shifts enhance travel experiences while presenting new challenges. Also, it recommends future tourism strategies emphasizing digital innovations, sustainability, circular economy, and social value to boost tourist experiences and destination competitiveness. Also, in the study [24], the researchers discuss the rise of Recommender Systems (RSS), especially Travel Recommender Systems (TRSs), as tools to mitigate information overload in sectors like e-commerce and e-tourism. TRSs provide personalized travel recommendations based on user's preferences. However, previous systems have overlooked user behavior. The authors suggest using the Activity and Behavior induced Personalized Recommender System (ABiPRS) to solve this. This hybrid approach includes user behavior to deliver Point of Interest (POI) suggestions that are more convincing. They also provide a brand-new group recommendation model that uses user connections. These novel strategies fared better than previous solo and standard hybrid approaches when evaluated on datasets from Yelp and TripAdvisor. Unquestionably, the advent of these cutting-edge tools and technology has great potential to improve tourism services, enhance visitor experiences, and streamline corporate processes in the sector.

Due to its growing impact on the tourist sector, which includes information search, decision-making practices, tourism promotion, and creating successful customer interactions, social media has emerged as a hot topic for research [43]. The qualitative study [23] investigated the substantial impact of social media on travelers' decisions, revealing its influence on six critical travel components—destination, transportation, lodging, food and eating, sights, and shopping and leisure activities. This influence, disclosed through interviews with 21 visitors, underscored four primary roles of social media in decision-making: acting as a need generator, supporter, guide, and approver. The authors also outline their results' theoretical and practical ramifications and recommend further study. According to [44], the tourism industry heavily depends on information technologies for promotions, sales, and customer relationships, with online word of mouth (eWOM) influencing tourists' destination choices. Researchers have noticed more tourists using digital media, leading to tailored offerings through advanced technologies. The emergence of Web 2.0 has transformed travel decision-making, with surveys showing that about 50% of people download travel apps for destination research before their trips. According to the literature, it is clear that the expansion and development of social media platforms have had a profound impact on the travel and tourism sector. They play important roles in influencing travel choices, reshaping how customers view places, and altering how business professionals handle promotions and client relationships.

Tourism sector stakeholders must recognize and accommodate this trend as more passengers rely on digital sources for information. Future study is urged to continue examining the psychological effects of social media on tourism, which will help the sector and its clients.

Recently, Virtual reality (VR) has been used as an alternative tool in the tourism and hospitality industries to improve tourists' user experiences and for marketing purposes. According to the existing research, Second Life has a wide range of possible applications, including the use of tourist marketing by a number of firms [29]. In [17], the study aimed to develop a framework informed by the Technology Acceptance Model and Hedonic Theory that would help design interesting 3D tourism sites and promote people's interest in the actual destinations. This framework would identify enjoyment, emotional involvement, positive emotions, and flow experience. According to [14], the study indicates that VR can revolutionize tourism planning and marketing by providing sensory-rich virtual tours. In [41], it suggests that post-COVID tourism recovery depends on arousing interest and positive emotions via products. The authors also propose a PEI framework outlining presence determinants and their impact on emotional responses and behavioral intentions, advocating for more research, especially on presence determinants' interaction with emotional responses in tourism. In the study [42], the researchers investigate virtual reality's role in tourism marketing. Through an experiment involving 72 participants, the researchers discovered that interactive VR environments evoke stronger positive emotions than traditional media, suggesting a shift in focus toward enhancing engagement mechanics in VR.

Other emerging technologies have also shown promise to improve experiences in tourism and hospitality worldwide. For instance, IoT-enabled smart hotels enhance the guest experience by using sensors for security, maintenance, and energy conservation, adjusting energy usage based on occupancy, and optimizing resource consumption [18]. Smart technology and ambient intelligence (AmI) enable real-time services, value co-creation, and enhanced consumer experience [6]. Also, in recent years, the surge in usage of mobile and web-based tools for users, including travelers and trip planners, has been facilitated by the broad availability of the Internet and affordable devices. For instance, Agoda, a user-friendly hotel booking and trip planning app in South-East Asia, has gained popularity due to its diverse content and positive user experiences. Globally, similar platforms like hotels.com, Expedia, and TripAdvisor have also grown in prominence. The appeal of these systems lies in their ability to offer a comprehensive travel planning platform, simplifying the process from purchasing airline tickets to booking hotel rooms and car rentals. According to [39], the widespread impact of the Internet on socioeconomic aspects of life is extensively documented. Yet, a lack of research explores how travelers' behaviors have evolved alongside Internet advancements. Leveraging data from national surveys conducted over six years (2007-2012), their study delineates the transformative trends observed in American travelers' Internet usage. The study reveals an emerging divide among online travelers: the traditionalists who rely on the Internet for conventional travel products and those exploring alternative platforms and offerings to seek more profound and unique user experiences. This research underscores the crucial implications of these trends, providing valuable insights for future studies and industry practices.

Cognitive Infocommunications (CogInfoCom) is a field emerging at the intersection of various disciplines, focusing on enhancing human cognitive capabilities through advanced technologies. It draws from anthropology, psychology, engineering, and more, uniting these fields to develop technologies like electronic calculators that enhance computational capacity and thereby cognitive functionality (Baranyi & Csapo, 2012) [46, 47]. As communication technologies evolve, CogInfoCom researchers study how users' cognition can co-evolve with devices such as mobiles and IoT sensors, emphasizing practical applications that enhance both individual and societal functions [51]. This multidisciplinary approach reflects the dynamic exploration within CogInfoCom, focusing on the interaction between human cognition and technological advancements. The concept of CogInfoCom is integral to our project as we aim to streamline the trip planning process, enhancing ease-of-use for tasks, navigation, and feedback. While existing literature has explored the implications of CogInfoCom in areas like technology for ageing [48] and virtual reality for social interaction [49, 50], research specifically addressing CogInfoCom applications within e-tourism and user experience remains limited. This gap highlights the potential for innovative applications of CogInfoCom principles in enhancing the digital travel planning experience, suggesting a need for further investigation into how cognitive and communicative interactions can be optimized in e-tourism platforms.

Drawing upon the review of existing literature, we have identified the importance of using emerging technologies to enhance tourists' experiences and plan a trip effectively and efficiently. Among these technologies, we've discovered several prevailing issues with the existing travel designing websites and applications. First, most sites and applications offer a particular function, such as accommodation booking, destination suggestion, or travel time estimation. This fragmented approach forces tourists to juggle between multiple platforms, leading to a disjointed and often frustrating user experience. Secondly, many popular platforms are developed and managed outside of Thailand. This results in recommendations that frequently spotlight popular tourist hubs, resulting in an overlook of unique local attractions in Thailand and a lack of personalization for tourists.

Additionally, the data provided by these applications often lack real-time updates and user feedback, negatively affecting user satisfaction. Furthermore, to the best of the authors' knowledge, there is a limited number of technologically advanced solutions dedicated to crafting personalized trip itineraries for tourists visiting Thailand. Recognizing these gaps, our study presents a unique proposition - a customized trip planning solution explicitly tailored for Thailand-bound tourists called 'NimBus.' This tool addresses the issues above and serves as a promotional platform for local businesses, significantly smaller enterprises that often miss out on substantial exposure. In line with the Economist Intelligence Unit's report [13] highlighting the growing global interest in

visiting Thailand, 'Nimbus' aims to be a comprehensive and personalized solution to this unmet demand. This study, therefore, presents 'Nimbus' as a timely and much-needed solution to enhance the travel experience in Thailand.

III. DESIGN THINKING

We opted for design thinking in this study for the following reasons. First, design thinking is an innovative, user-centric approach to product creation and problem-solving [15]. Second, it requires comprehending user requirements, testing presumptions, and developing alternate solutions. Third, it incorporates five non-linear iterative stages: understanding consumers' requirements through empathy, identifying key issues, formulating potential fixes, prototyping both the low-fidelity and high-fidelity versions of the product, and testing the prototype to obtain users' feedback [12]. To execute the study, 'emphasize' was the first step of the design and development process, during which our group discussed design concepts and developed a list of potential target audiences for more research. Surveys and interviews were used to get users' input and feedback on their requirements and issues. Moving on to the 'define' stage, various analysis tools and diagrams aid in narrowing down the project's scope and confirming the problem to be addressed on behalf of target users. Subsequently, the 'ideate' stage involved designing the solution to the identified problem, utilizing additional tools to generate functionalities and features for incorporation into the system prototype. The 'prototype' stage entailed crafting highly detailed user interfaces and devising evaluation plans to refine the design before implementation. Finally, in the 'test' phase, internal testing was conducted to refine and enhance the system before its official release. This section of the report will delve into the specifics of each stage as they relate to our trip planner web application.

A. *Understand Target Users*

During the 'empathize' phase of the project, we identified our target users as international tourists planning to visit Thailand in the post-COVID-19 era and domestic travelers interested in exploring different destinations within Thailand. We harnessed qualitative data by conducting structured and semi-structured interviews with university students in Thailand. This group included native Thai and foreign exchange students, and our goal was to understand and empathize with their trip-planning experiences, the resources they used, and the challenges they faced during and after the planning process. Additionally, we engaged with international tourists already in Thailand to fulfill similar objectives. Each interview lasted roughly 30 minutes, facilitated through a hybrid, either online or in-person, depending on the interviewee's convenience. We also obtained quantitative data via questionnaires containing 12 questions. These questions revolved around users' travel preferences, such as budget, location, duration, and type, along with difficulties they encountered during and post-trip planning and their motivations to plan or opt out of planning a trip. The insights from 35 interviews and 77 questionnaire responses underlined that users' primary concerns included modes of transportation, the reliability of tourist spot reviews, safety and cleanliness of accommodations, and the ability to stick to their plans amid unpredictable events. Notably, 92.2% of respondents regularly plan their trips, leaning on social media reviews, recommendations from friends, and YouTube videos as their guide. The remaining 7.8% chose not to plan their trips, mainly due to time constraints or lack of effort. In summary, the gathered data bolstered the idea that most participants preferred trips with prearranged itineraries while simultaneously acknowledging the challenges associated with trip planning. In relation to the difficulties experienced while planning a trip, we discovered that the current resources available were inadequate for tailoring a trip according to individual preferences. Furthermore, these tools were primarily geared toward promoting popular tourist attractions in Thailand. They fell short in providing information about lesser-known, yet worthy destinations (e.g., temples, beaches, and local eateries), creating a gap in comprehensive and personalized travel planning.

B. *Define User Needs*

Following the user requirement collection process, which included interviews and questionnaire surveys, we systematically classified the raw data to extract insights relevant to each target group. This data, in turn, informed the creation of two empathy maps, delineating our audiences' pain points and gains [21]. For this study, two distinct empathy maps were crafted (see Fig. 1), one for Thai students (local travelers) and another for international students (international tourists). Using these empathy maps as a foundation, we constructed two personas—fictional characters that encapsulate the characteristics of each target audience [16]. In this scenario, we crafted one persona to represent Thai undergraduate students aged 18-22 and another to represent international students under similar conditions (see Fig. 2). Subsequently, we developed a customer journey map—an 'as-is system'—to visually represent the sequence of experiences a customer goes through in traditional trip planning (see Fig. 3). With two personas and a customer journey map, we formulated How-Might-We (HMW) questions to address the personas' identified pain points and needs effectively. In this

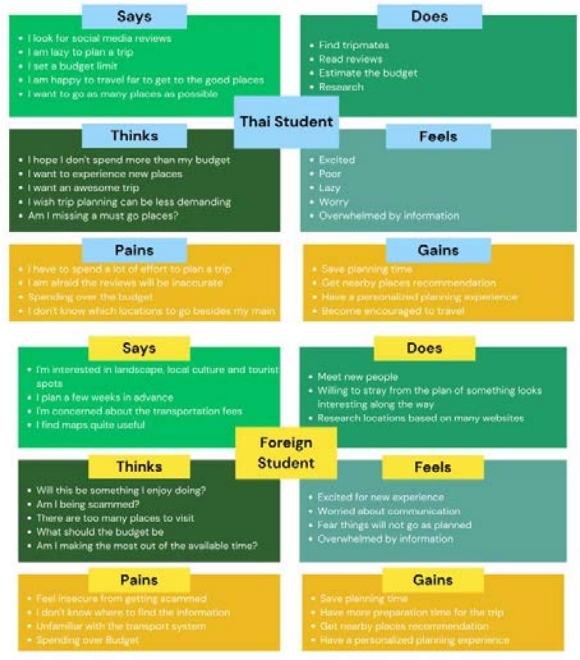


Fig. 1. Empathy maps

Fig. 2. Local student persona (above) and international student persona (below)

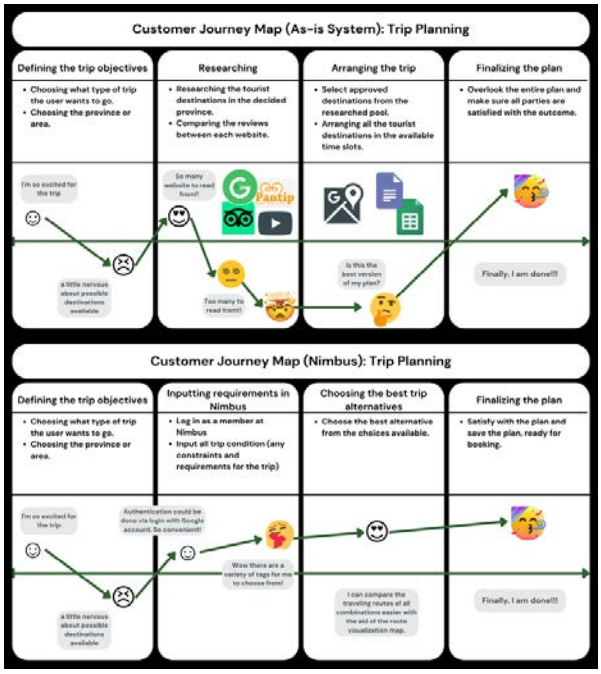


Fig. 3. Customer journey maps

study, our HMW questions included: 'How might we streamline the personalized trip planning process for tourists and create seamless experiences for them?', 'How might we promote lesser-known destinations in Thailand so that we can promote Thailand's tourism industry?' and 'How might we promote local businesses via the NimBus application?' These questions will guide the following stages of our project as we strive to provide solutions that address these challenges.

C. *Ideation*

During this phase, a brainstorming session focused on the aesthetic and technical aspects of our trip planner web application, outlining essential features based on users' needs. This early approach allowed for task allocation and efficient workflow management. We used insights from the definition phase to shape solutions and articulate system requirements, transforming them into application features. Our design was regularly reviewed and adjusted to better align with user needs. As mentioned previously, the primary goal of our solution is to streamline the complex and time-consuming process of trip planning; hence, we propose an approach that lets users input their preferences, after which they receive a customizable itinerary, reducing the complexity of self-coordinated trips while allowing for personalization. Users can further tailor the auto-generated itinerary.

Additionally, the 'NimBus' advanced algorithm provides recommendations tailored to users' interests, budgets, and time, which includes famous and unique attractions in Thailand. This offers a comprehensive, personalized exploration experience. Through a specific function and feature analysis, we revised our original design elements. For instance, the 'Plan Trip' function initially aimed to speed up trip planning, but we identified areas for further optimization. We replaced the quick initial quiz with a 'Choose Preset' function, allowing users to swiftly select and save pre-configured plans. This change streamlines planning and enhances user experience. We utilized a mind map to understand our project's functions, especially post-modifications (see Fig. 4), visually representing the primary use case. Predominantly, these functions stem from user insights. Table 1 presents the functionalities of the 'NimBus' application, formulated based on user needs and insights.

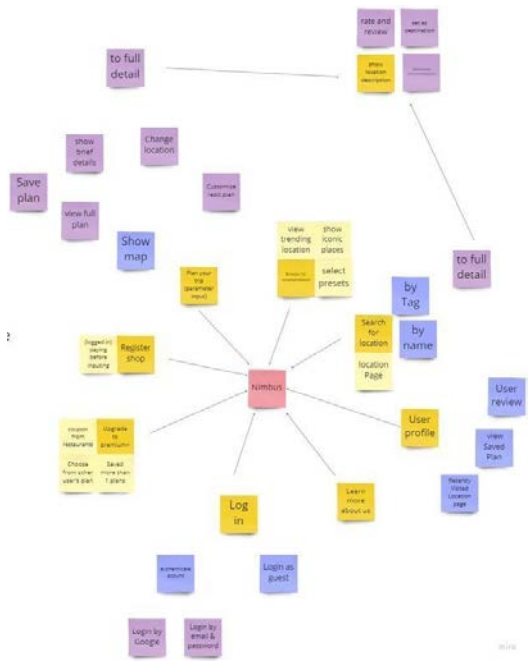


Fig. 4. Mind map

TABLE I.
SYSTEM'S FUNCTIONALITIES TABLE

The Main Features	How the feature helps as a solution
Plan Trip	This feature allows users to make an easy and quick trip plan with a detailed schedule and a map from the Google API by simply inputting various parameters onto the web. The user will also be able to customize their preference through the edit plan further and add and delete location functions.
Location Page	This feature allows the users to gather more information about the place in their Schedule or what they are interested in with detailed descriptions and a rating, along with reviews from other users on the site. The user can also select the location to be a destination in their trip plan.
Search for Location	This feature allows users to search on the web by location name or by their tags, which is part of the parameter to create a plan, to see the location they might be interested in. The user will not have to do much research on multiple sites.
Browse from recommendation	This feature gives users some recommendations about the places they might be interested in, so they don't have to go and do too much research on their own. The features can be separated into choosing presets, viewing iconic places, and trending locations.
Check User Profile	The user can view their saved plan here, revisit any location page they have recently visited, and see all the collective reviews they have posted on the site.
Log In	For the plan to be saved by a user, they must create an account to store their plan data.
Learn More About Us	The user can learn more about the site's creator and acquire a way to contact the creator when faced with questions and wants to ask for information.
Upgrade to Premium	This feature will allow users to access a more upgrade experience while helping the web maintain operations to help them with all their plans.
Register Shop	This feature allows the shop owner to advertise their shop and be included in the plans of our users, helping the shop owner generate more income and help users discover new places to visit.

TABLE II.
SYSTEM'S FUNCTIONALITIES TABLE

Principles	Applications in 'NimBus'
Fitts's Law	We strategically designed and placed crucial buttons like "Plan now," "Set as plan," "Edit," and "Select as a destination" on our digital platform. This enhances user experience by improving visibility, accessibility, and intuitive interaction with key features on both desktop and mobile.
Hick's Law	Our platform uses a step-by-step approach for trip planning, enhancing usability, and minimizing cognitive load. Users see a brief, actionable trip plan with additional features upon expansion. The initial interface showcases the first day's plan, with options to see more days or explore alternate locations, providing a tidy and flexible user experience.
Miller's Law	The navigation bar should have 5-9 items for a clean user experience. We've added a budget input field with automatic thousand separators for improved readability and user-friendliness.
Postel's Law	We'll implement an intelligent location input field for a better user experience, providing autocomplete suggestions. The budget field will only accept positive integers, and date fields will restrict past dates or illogical durations, enhancing accuracy and reducing confusion.
Aesthetic-Usability effect	Our app features a relaxing theme with a color palette drawn from calming travel elements. Rounded corners on components add visual comfort, while subtle transitions and animations enhance engagement. Overall, the design promotes a welcoming, enjoyable trip-planning experience.
Tesler's Law	Our application will include a feature to swap locations without restarting planning, boosting efficiency. We'll improve date fields with a calendar pop-up for simpler, error-free selection, making the planning experience more intuitive.
Doherty Threshold	The system will respond to user inputs within 400 ms to increase efficiency. We'll include a loading animation for longer tasks, keeping users informed and maintaining progress, improving the user experience.

As we prepare for the prototype phase with our core features, we must adhere to vital UX/UI principles. Firstly, simplicity and consistency are key for high user engagement and easy navigation. Secondly, optimizing responsiveness and speed enhances user satisfaction. Lastly, a good visual hierarchy guides users through the application, improving their experience. These principles, referenced in Table 2, will help us create a user-friendly, engaging web application. Applying these UX/UI principles will make our prototype functional and visually appealing.

D. Prototyping

The 'prototype' phase focuses on developing our web application's functionality and design based on user research insights. Each prototype iteration is refined through early usability tests. We began by creating basic, low-fidelity UI sketches, thoughtfully considering the placement of key components, screen layout, and app navigation. We then engaged in constructive discussions about the strengths of each sketch, which were subsequently integrated into a cohesive, low-fidelity UI design once we reached team consensus on the primary layout for essential web application

elements. Utilizing a combination of specific requirements and established UX/UI principles, we crafted a low-fidelity UI design focused on embodying the core functionalities of the application. Fig. 5 shows the low-fidelity prototypes of 'NimBus.'

Fig. 5. Hamburger menu and register place pages

1) Early Usability Test: Upon creating a low-fidelity prototype in Figma, the UX/UI team launched an early-stage evaluation and usability test to gather feedback on our interfaces. Given 'Nimbus' primarily serves Thai and foreign tourists and partner store owners, our user research was structured accordingly, involving six participants. Interviews, primarily conducted online, began with consent to record and use the session results. Participants tested the 'Nimbus' prototype and provided feedback on the completion of tasks. Results were logged into a Google Sheet for analysis. Initial feedback was encouraging, with users appreciating the app's visual appeal, coordinated color scheme, and intuitive interface. However, issues like inconspicuous arrow keys, random logout button placement, and ambiguous input options needed addressing. Unforeseen user interactions also provided valuable insights for user experience enhancement. In response, minor tweaks made the app more user-friendly, such as linking the 'Nimbus' logo to the homepage and adding location descriptions in plan details. The visibility of the 'next days' arrow was enhanced, the logout button was repositioned, and input options during plan generation were clarified. A fundamental improvement, strengthening the 'next days' arrow visibility, was guided by Fitts's law, increasing its size and clarity without disturbing the layout.

E. Hight-Fidelity Prototypes

Following an insightful round of the initial usability testing for 'NimBus,' we have streamlined and augmented the user interface and overall user experience. Expert advice and constructive criticism from UX professionals have been instrumental in this improvement journey and are now seamlessly woven into the design enhancements. The evolution of this process culminated in the final and high-fidelity prototypes of 'NimBus.' A showcase of the interface is depicted in Figure 6. The 'Home Page' serves as the heart of our platform, featuring a captivating banner that spotlights famous tourist sites across Thailand.

Fig. 6. Home page of '*NimBus*'

Furthermore, it also brings attention to 'trending' local gems that users might be intrigued to explore, encompassing a wide range of temples, shopping malls, museums, and gastronomic hotspots. One unique aspect of the home page, as illustrated in Figure 7, is the keyword-search feature. Users can enter specific interests or preferences, generating 'tags' such as 'art,' 'food,' or 'shopping.' This tailored approach facilitates an enriched exploration experience that aligns with individual user tastes. The algorithm-generated local attractions are another unique aspect of our service.

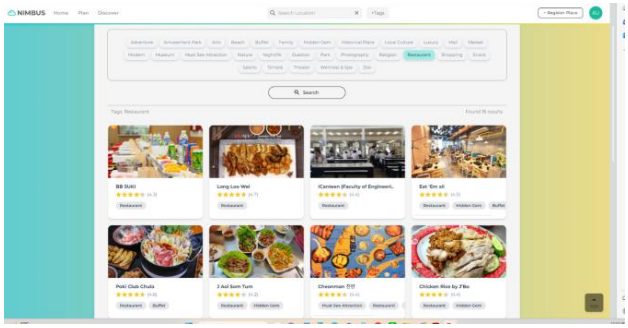


Fig. 7. User' tags

Furthermore, the local businesses (e.g., restaurants) are incorporated into the recommendation list based on the user's preferences and input parameters. Figure 8 provides recommendations such as 'Wat Hua Lamphong,' an iconic local temple less known to international travelers, thus creating an authentic, off-the-beaten-path travel experience.

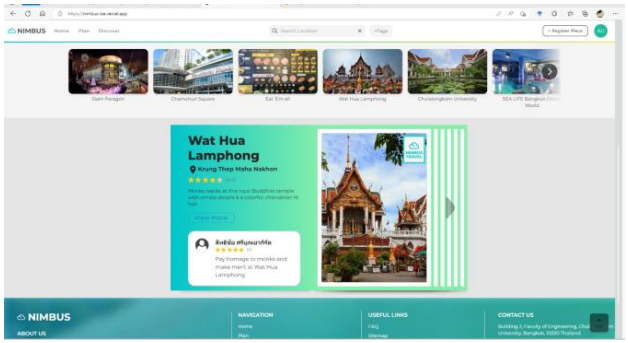


Fig. 8. A local place recommended by NimBus

Transitioning to the 'Planning Page,' users are empowered with customizable planning parameters, depicted in Figure 9. Users can specify their desired destinations, dates, and trip duration. They can also choose their travel style, for instance, 'adventure,' 'budget,' and 'mode of transportation.' After inputting these planning parameters, the system curates a comprehensive itinerary tailored to the user's preset preferences. The meticulously crafted trip planning, displayed in Figure 9, spans over three days, presenting a myriad of suggested locations for each day. Each recommended place comes with user reviews and essential information, fostering an informed decision-making process for the user (see Fig. 10). Should they wish to modify a specific location in their itinerary, a simple click on the 'edit' button provides alternate suggestions (see Fig. 11). Our map visualization feature, shown in Figure 12, aids users in understanding the distances between the recommended locations.

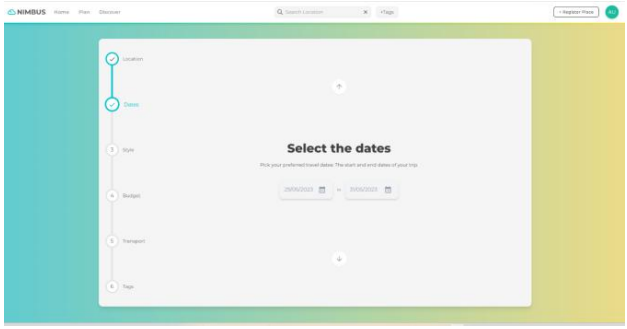


Fig. 9. Plan page

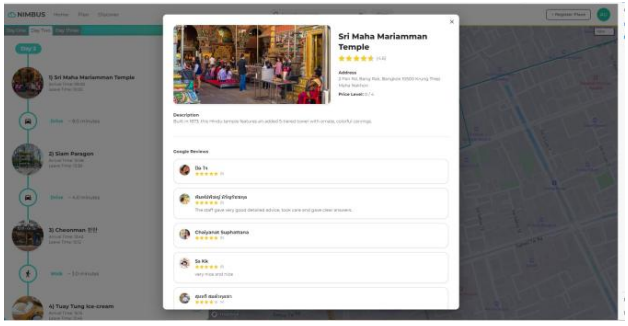


Fig. 10. Users' reviews

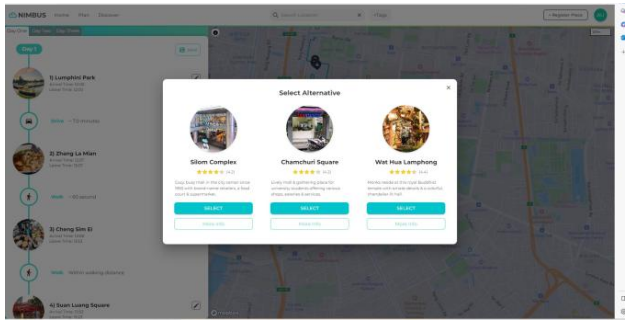


Fig. 11. Alternative destinations

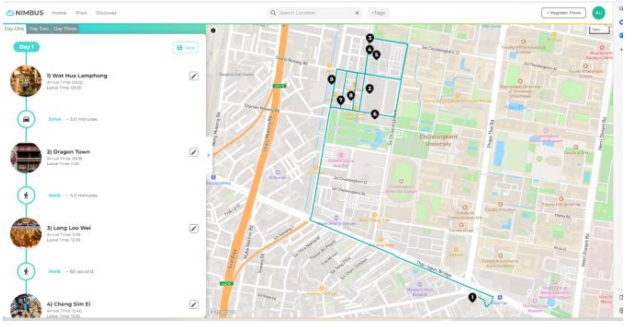


Fig. 12. Trip plan and map visualization

Additionally, it includes practical information such as estimated travel time and mode of transport, enabling users to make efficient travel decisions. Fig. 13 shows the overview of a 3-day trip plan generated by 'NimBus' based on the user's preferences. Any user pleased with the system-generated itinerary can save it within the system for easy retrieval upon subsequent logins, as seen in Figure 14. In addition, 'NimBus' provides a comprehensive user profile page where users can update their information and access current and past trip plans. Our algorithm personalizes the trip plan for repeat users of 'NimBus' based on their historical data (e.g., places visited). This feature significantly enhances the user experience, making each travel plan as unique as the user.

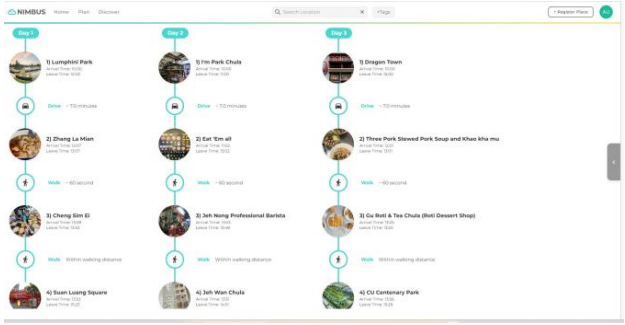


Fig. 13. Overview of the trip plan

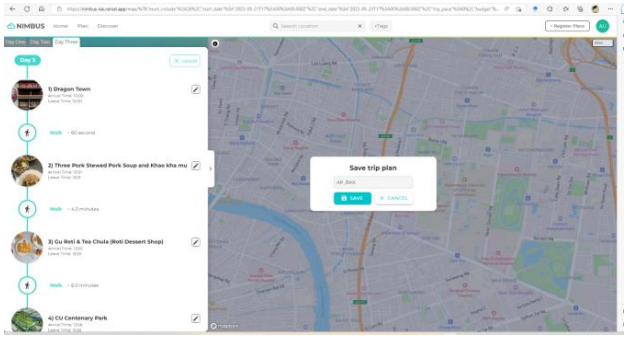


Fig. 14. Save plan

F. Development

Our system design utilizes a client-server framework, and RESTful API, facilitating efficient user-server communication. Developed with Next.js, the front end offers

server-side rendering for performance optimization. Its built-in features improve the development experience. This front end is deployed on Vercel, relieving developers from managing servers or infrastructure. Our backend uses Flask, integrating our Python-coded personalized itinerary algorithm. Flask's readability, simplicity, and database connectivity support a scalable web application, with the large developer community offering resources and assistance. We host this backend on Google Cloud, ensuring scalability and reliability while easing management through Cloud Logging and Monitoring tools. Our database, built on AWS using PostgreSQL, provides scalable and reliable data storage. The combination of PostgreSQL and AWS results in a resilient data storage solution. The system architecture design is depicted in Fig. 15.

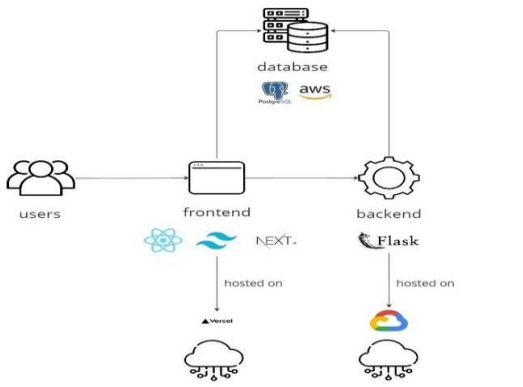


Fig. 15. System architecture design

G. NimBus's Algorithm Design and Development

Our trip-planning algorithm was designed and adapted from the study [22]. The algorithm in our study has been tailored to meet our unique specifications in creating personalized itinerary recommendations for travelers to Thailand. Generally, the Personalized Itinerary Recommendation problem (PIR) can be viewed as a non-linear problem, as selecting the destination location with the highest score sequentially is not feasible. Hence, our objective is to maximize the overall score of the entire itinerary, ensuring that the generated itinerary has the highest level of satisfaction compared to all other possible variations. To address this challenge, we have adopted the variation of the Monte Carlo Tree Search (MCTS) algorithm, which evaluates each state by averaging scores of simulations from that state. Unlike traditional minimax search algorithms, which consider all possible moves from a state, our MCTS approach considers the probabilistically best moves [2]. This characteristic proves advantageous when dealing with large search spaces that exhibit high branching factors, which is particularly suitable for the PIR problem due to the abundance of Points of Interest (POIs).

Furthermore, the MCTS algorithm offers a great deal of flexibility. It enables us to modify the scoring function according to our specific needs, thereby allowing us to effectively promote hidden gem locations in Thailand to users or travelers. By leveraging this adaptability, we can tailor the algorithm to provide personalized recommendations highlighting Thailand's unique and lesser-known attractions and businesses. Our algorithm also used the modified Monte Carlo Tree Search (MCTS) approach, consisting of three main steps: Selection, Expansion, and Backpropagation. Initialization begins with an empty tree and initializes the root node with all possible Points of Interest (POI) as a starting location (see Fig. 16).

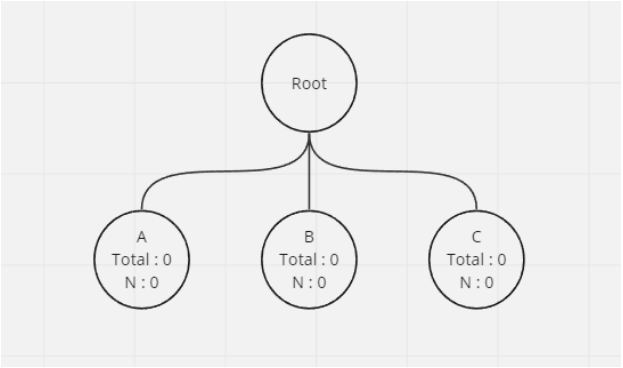


Fig. 16. Initialization

As shown in Fig. 17, it selects the highest score POI based on a scoring function.

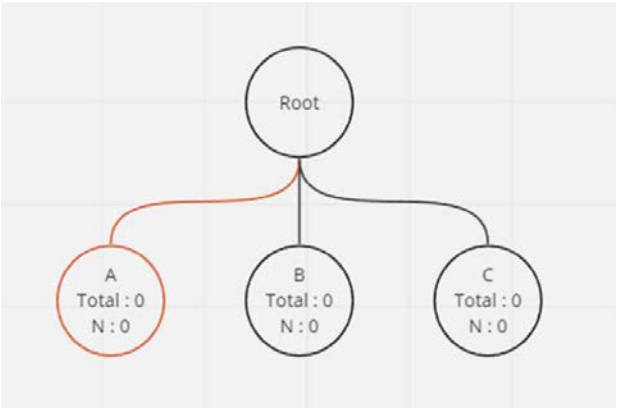


Fig. 17. Selection

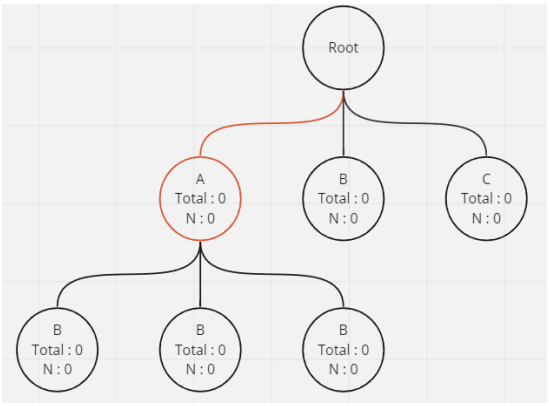


Fig. 18. Expansion

For expansion, as displayed in Fig. 18 and 19, it populates all available POI candidates that could be selected as the next destination, considering time constraints such as opening, closing, trip ending, and meal times. Then, it appends these POIs as children of the selected POI node from the previous step. (node A for this example). After that, it repeats steps 1 and 2 until the end of an itinerary is reached. (when the time has gone over the trip ending time).

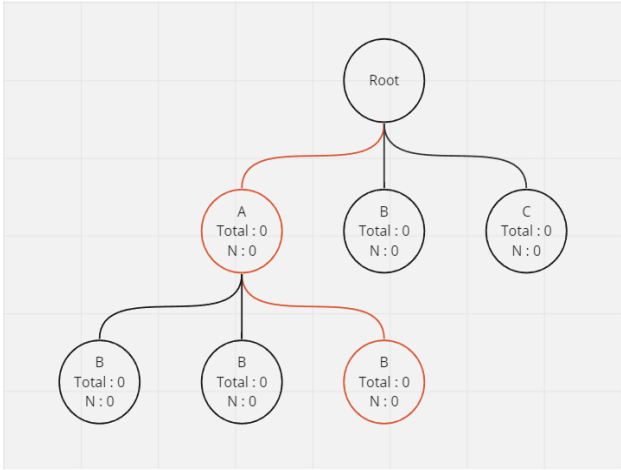


Fig. 19. Repetition

For backpropagation, when the end of the itinerary is reached, it propagates the total score and visit count(N) back up the tree (see Fig. 20).

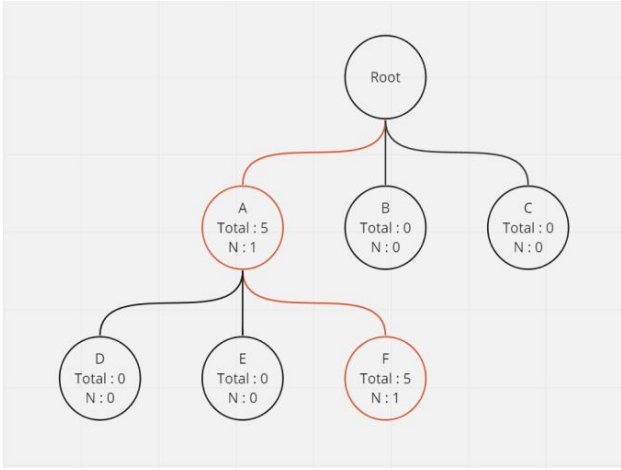


Fig. 20. Backpropagation

Then, this completes one cycle of the algorithm and repeats this process for 10,000 cycles to generate the final tree, which will be used for itinerary generation (see Fig. 21).

For itinerary generation, it selects the final itinerary by traversing the tree to the leaf and choosing the node with the highest average score per visit (total/N) (see Fig. 22).

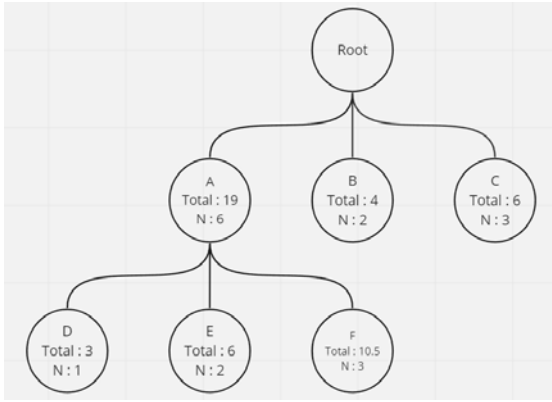


Fig. 21. Generating the final tree for itinerary generation

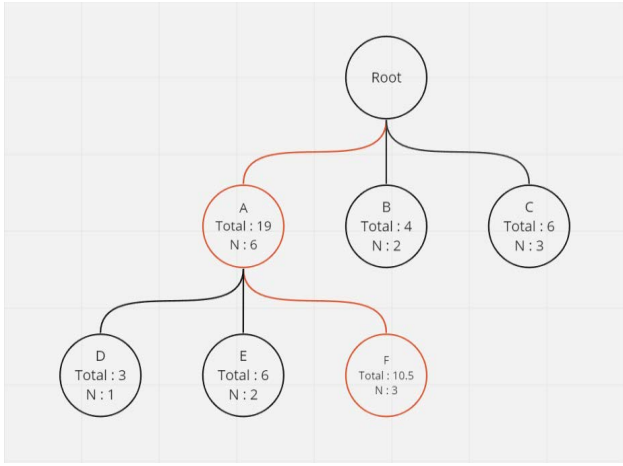


Fig. 22. Itinerary generation

The scoring function consists of two types of score: exploit score and explore score. First, for 'Exploit Score' represents the quality of the POI and is calculated based on factors such as location rating(S_rating), user-selected tags(S_tag, and travel time(D_ij). For 'Explore Score,' encourages the algorithm to explore new POI and is calculated using the formula shown in Fig. 23. Ns represents the visit count of the starting node, and Nd represents the visit count of the destination node. The explore score increases as the difference between Ns and Nd increases. In summary, this algorithm generates a user-centric and personalized trip plan with itinerary details for our target users.

$$exploit = \frac{S_{tag}^{(d)} + S_{rating}^{(d)}}{1 + D^{(s,d)}}$$

$$explore = C * \sqrt{\frac{1 + N_s}{1 + N_d}}$$

Where s = start, d = destination

Fig. 23. Exploit and Explore scores

IV. METHODOLOGY

Conducting usability testing with our target users is crucial to assess the usability, efficiency, and effectiveness of 'NimBus.' This procedure empowers us to collect invaluable user feedback, vital in developing a digital product that fulfills the target users' requirements [31]. Our primary objective is to achieve measurable and quantifiable results through usability testing. By doing so, we aimed to validate the functions and features of our web application, 'NimBus,' ensuring that it aligns with users' preferences and requirements. During the usability testing process, we focused on assessing three critical aspects of the system: system usefulness, information quality, and interface quality. Besides these metrics, we intended to supplement our data with quantitative feedback through questionnaires and qualitative insights using open-ended interview questions. This comprehensive feedback would provide an in-depth understanding and shed light on areas for potential improvement.

The first step to a successful usability test is recruiting appropriate participants. We aimed to recruit a minimum of 10 participants to ensure the credibility of the test results. The participants were selected based on the personas we created during the 'define' phase of design thinking. Our target user groups included Thai university students, foreign/exchange students, and business owners in Thailand. Once we had our participants, the usability testing was carried out as planned. The user interviews would primarily be conducted online, in line with the preferred communication mode of our target user groups, as well as the COVID-19 guidelines by the university. However, when necessary, in-person sessions were also undertaken with permission. In the study, at least two researchers were undertaking the test. For instance, one researcher could record test results on their devices, while the other researcher would ask interview questions to the participants. In addition, task completion time, error rate, task duration, and further participant comments would be logged into our shared project spreadsheet and Google forms for post-test questionnaires. The usability testing process could be broken down into three phases: pre-test, in-test, and post-test, as illustrated in Table 3. The participants were given an overview of the project and the testing procedure during the pre-test to use the test results for our study. If the test was administered online, we recorded the session. Before moving on to the in-test phase, we ensured each participant understood the testing method after obtaining the consent. The activities were presented, and the researcher recorded the participant's completion time during the in-test phase. The researcher would then only become involved when required, as when a participant seemed disoriented or encountered difficulties. Before the person tried the task assignment again, any problems, misconceptions, or need for an explanation would be addressed. Each task's duration and any challenges encountered will be noted after completion.

Upon completing all the participant tasks, we would commence the post-test section, beginning with a series of post-test questionnaires. This segment involved three distinct questionnaires: the System Usability Scale (SUS), the Post-Study System Usability Questionnaire (PSSUQ), and the Net Promoter Score (NPS). According to [33, 41], the SUS offers a reliable, practical assessment of perceived ease of use and

TABLE III.
USABILITY TESTING DESIGN AND PROCEDURE

Section	Procedure	Estimate Duration
Pre-Test	Introduction to the Project and the Usability Test	2 mins
	Request for consent	2 mins
In-Test	Task 1 - 6	2 mins
	Post Task Interview	1 min
	Task 7 - 15	4 mins
	Post Task Interview	1 min
	Task 16 - 19	2 mins
	Post Task Interview	1 min
Post-Test	Post Test Questionnaire (e.g., SUS, PSSUQ, and NPS)	3 mins
	Post Test Interview	5 mins

TABLE IV.
TASKS DESCRIPTION

No	Task description is given to users	Function
1.	Locate the Login/Sign-up function.	Authentication
2.	Look for an Iconic place and go through it	Browse for Recommendation
3.	Search for the Location Details of a place called '*Chamchuri'* Square	Location Detail
4.	Locate the Comment section for the review of '*Chamchuri'* Square	Location Detail
5.	Set '*Chamchuri'* Square as a destination to visit	Location Detail + Plan Trip
6.	Go back to the Home page.	Home Page
7.	Create a trip plan	Plan Trip
8.	Find more details about '*Chamchuri'* Square on the schedule page	Plan Trip
9.	Change "*SamyarnMitrtow*'n to "*Siam Paragon"* for the location to visit	Edit Plan
10.	Change the visiting order to go to "*Siam Paragon"* before "*Chamchuri"* Square.	Edit Plan
11.	Delete Siam Paragon from the list of locations to visit	Edit Plan
12.	Show Schedule for Day 3	Plan Trip
13.	Show Full Schedule	Plan Trip
14.	Save Plan	Plan Trip
15.	Go to the User Profile Page	User Profile
16.	Visit the "*Chamchuri"'* Square location page you visited before through this page.	User Profile + Location Detail
17.	View your saved plan.	User Profile + Plan Trip
18.	Request to register your store or place it into the system	Register Shop
19.	Find the sign-out function.	Authentication

learnability, utilizing a 5-point Likert scale. Similarly, the PSSUQ is a standardized tool designed to gauge the participant's satisfaction with the product, typically websites or software, using a 7-point Likert scale [34]. Lastly, the NPS is a loyalty metric, providing insights into whether the participant considers the product they are testing highly usable; it operates on a scale of 0-10 [4]. After finishing the final task in the test section, participants would receive a Google form containing 27 questions: 10 for the SUS, 16 for the PSSUQ, and a single question for the NPS. Once the post-test questionnaires were completed, participants would proceed to the post-test interview questions. These questions are designed to gain deeper insights into the performance of the current web application, facilitating future analysis and revisions. The research would document the participant's responses in a shared spreadsheet. After all interview questions had been addressed, recorded, and documented, the interviewer would notify the participant that the usability testing session had concluded.

V. Results and Findings

In our study, 10 participants, a blend of Thai and foreign exchange students, participated in the usability test. Averaging 21 years, our participants presented a gender distribution of 6 males and 4 females, while 3 of them were French, German, and Indonesian nationalities. They are currently enrolled in undergraduate studies at a Thai university. Each had prior experience planning at least one trip within Thailand or abroad, demonstrating their familiarity with digital trip planning tools like Airbnb, Agoda.com, Skyscanner.net, and Hotels.com. Our pre-study interviews found that participants mainly used existing tools such as Google Search and TripAdvisor for travel information, while a few experimented with AI tools like ChatGPT. This displayed an interesting shift towards AI in travel planning. We also delved into how participants perceive social media as a source of travel inspiration, their comfort using mobile booking applications, and their preferences in user interface designs. These findings provided valuable insights into today's tech-savvy travelers' prevailing habits and preferences. However, our goal extended beyond merely understanding their existing behaviors. We sought to identify potential areas of improvement and innovation in our digital solution 'NimBus' to create a more intuitive, user-friendly tool that aligns with modern travelers' changing trends and needs.

A. System Usability Scale

We analyzed and interpreted the data of the system Usability Scale (SUS) using a dataset containing mean scores and standard deviations across ten items (SUS1-SUS10). The results suggest that the system performed well in terms of perceived usability. The mean scores for positive items (SUS1, SUS3, SUS5, SUS7, and SUS9), which assess aspects such as ease of use and user confidence, were consistently high, ranging from 4.1 to 4.5 on a 5-point scale. These high mean scores demonstrate that users have a favorable perception of the system's usability, finding it intuitive and user-friendly. In particular, the trip planning task by 'NimBus' was found to be easy to use (SUS3, M = 4.5, SD = 0.707), and the users felt very confident while using it (SUS9, M = 4.4, SD = 0.699). On the other hand, mean scores for negative statements (SUS2, SUS4, SUS6, SUS8, and SUS10), which reflect the complexity, technical support requirement, inconsistency, and learning curve of the system, are noticeably low, ranging from 1.2 to 1.7. These low scores indicate that users did not encounter significant usability issues or challenges with the design, consistent with positive SUS items. For instance, users did not find the system unnecessarily complex (SUS2, M = 1.5, SD = 0.707) and did not need immediate and substantial technical support to use it (SUS4, M = 1.2, SD = 0.632). Additionally, the standard deviations for each of the ten categories are less than 1, which shows that responses were primarily centered around the mean and suggests that users' opinions on the system were generally in accord. As shown in Table 5, the System Usability Scale (SUS) analysis highlights a high level of satisfaction among users concerning the perceived usability of 'NimBus.' The consistency in these responses, reflected in the low standard deviations, further reinforces these findings. Thus, the system demonstrates exceptional usability based on this analysis, suggesting a well-received and user-friendly interface. In summary, respondents found the system easy to use, its functions well-integrated, and they felt confident in their usage. They also did not consider the system complex or inconsistent, nor did they believe they required extensive technical support or additional learning to use it effectively.

TABLE V.
SYSTEM USABILITY SCALE RESULTS

SUS Items	Item Description	Mean (M)	Standard Deviation (SD)
SUS1	I would like to use this system frequently.	4.1	0.99
SUS2	I found the system unnecessarily complex.	1.5	0.71
SUS3	I thought the system was easy to use.	4.5	0.71
SUS4	I think that I would need the support of a technical person to be able to use this system.	1.2	0.63
SUS5	I found the various functions in this system were well integrated.	4.5	0.53
SUS6	I thought there was too much inconsistency in this system.	1.4	0.70
SUS7	I imagine most people would learn to use this system very quickly.	4.5	0.71
SUS8	I found the system very cumbersome to use.	1.7	0.82
SUS9	I felt very confident using the system.	4.4	0.70
SUS10	I needed to learn many things before I could get going with this system.	1.3	0.67

We also quantitatively analyzed the individual SUS scores, encompassing 10 participants labeled P1 to P10. Based on the individual SUS results, the total SUS scores ranged from 60 to 100, with a total mean SUS score of 87.25, higher than 68. This is supported by the existing literature that, according to Sauro (2011), a SUS score above 68 can be considered 'above average,' and anything under 68 is labeled 'below average.' The standard deviation score was approximately 11.99, indicating some variability in the SUS

scores. The participant data shows a range of responses about usefulness, quality, and satisfaction. We divided participants' replies into metrics for our evaluation, such as SUS individual total scores, adjective rating, grade, acceptability, and percentage. The overall SUS scores for our 10 participants vary from 60 to 100. Most participants (P1, P2, P3, P4, P6, P7, P8, and P9) had a usability score of 85 or higher, regarded as an 'Excellent' result. P6, P7, and P9 even received ratings of 97.5 and 100, which are close to the top of the scale and denote a 'Best Imaginable' level of user experience. As stated in [3], the SUS adjective rating is another interesting metric. Most participants were characterized as 'Excellent' while some reached the highest descriptor of 'Best Imaginable.' Only one participant, P10, was described as 'OK,' suggesting room for improvement.

Regarding grading, eight out of ten participants received an 'A+' grade, implying high satisfaction with the system. Participant P5 received a 'B+,' and P10 scored the lowest with a 'D.' It is possible that P10 encountered more usability issues or found the system less intuitive than the others. When we look at the 'Acceptability,' it is 'Acceptable' for nine out of ten participants and 'Marginal' for one participant, again P10. This implies that while most participants found the system usable and satisfactory, certain aspects might need further improvement to cater to all types of users. The percentile ranges indicate the position of these participants' scores within a broader comparison group. Most of our participants (80%) are in the top 96-100 percentile, indicating that users find the product or system highly usable and well-designed. Only one participant, P5, fell into the 85-89 percentile range, and P10 was in the lower 15-34 percentile. From these results, it is clear that most participants found the system highly usable and satisfactory, indicating a successful user experience design. However, the lower scores from participants like P5 and especially P10 suggest that there might be areas in which the system's usability could be improved.

TABLE VI.
INDIVIDUAL SYSTEM USABILITY SCALE RESULTS

Participants	SUS Total Scores	Adjective Rating	Grade	Acceptability	Percentile
P1	85	Excellent	A+	Acceptable	96-100
P2	90	Excellent	A+	Acceptable	96-100
P3	85	Excellent	A+	Acceptable	96-100
P4	87.5	Excellent	A+	Acceptable	96-100
P5	77.5	Good	B+	Acceptable	85-89
P6	97.5	Best Imaginable	A+	Acceptable	96-100
P7	100	Best Imaginable	A+	Acceptable	96-100
P8	90	Excellent	A+	Acceptable	96-100
P9	100	Best Imaginable	A+	Acceptable	96-100
P10	60	OK	D	Marginal	15-34

B. Post-Study System Usability Scale

The Post-Study System Usability Questionnaire (PSSUQ) was used to objectively assess participant views as part of the "NimBus" usability study. System Usefulness (SYSUSE), Information Quality (INFOQUAL), and Interface Quality (INTERQUAL) were the three main dimensions of the questionnaire. It's important to note that in the PSSUQ, the lower the score, the more favorable the results are. The application's System Usefulness (SYSUSE) was evaluated highly by users, as suggested by an overall mean score of (M=1.65, SD = 0.497). For each item of SYSUSE, users found the system to be easy to use (M = 1.3, SD = 0.674), simple to use (M = 1.3, SD = 0.483), and felt comfortable using it (M = 1.5, SD = 0.527). The capacity to execute tasks rapidly had a somewhat higher mean score (M = 1.9, SD = 0.876), indicating space for system efficiency improvement. The system's learning curve was also steeper (M = 2, SD = 1.826), indicating the need for stronger initial training or more user guidance. A little higher than the SYSUSE score, Information Quality (INFOQUAL) has a mean M= 2.09 (SD = 0.517). Users regarded the system's error messages as helpful in solving issues (M = 2.9, SD = 1.174) but gave it a lower rating for its capacity to correct itself (M = 2.25, SD = 1.087). This could suggest the system's information quality regarding error handling and recovery procedures must be improved. The system's information clarity was rated as acceptable (M = 2.6, SD = 2.191), while the accessibility of the necessary information was rated as good (M = 1.7, SD = 0.823). Users thought the information on the system panels was organized (M = 1.5, SD = 0.707). According to the INTERQUAL results, the system earned an overall mean score of M=1.67 (SD = 0.177) on the interface quality, showing that most users were content with it. Users also believed the system had all the required features and capabilities (M = 1.6, SD = 0.966), while the interface was easy to use (M = 1.8, SD = 0.632). Finally, the overall PSSUQ score suggests that users were satisfied with the system (M = 1.5, SD = 0.7), indicating a positive assessment of its usability covering usefulness, information, and interface qualities.

These results highlight several important aspects of the 'NimBus' system (see Table 8). The high System Usefulness (SYSUSE) and Interface Quality (INTERQUAL) scores suggest that users found the system usable and the interface pleasant. The slightly lower Information Quality (INFOQUAL) score could be due to the system's error messages and the perceived difficulty in recovering from mistakes, indicating potential areas for system improvement. The scores also suggest that while users are comfortable with the system's interface and can easily navigate it, some struggle with its learning curve. More intuitive system guidance or tutorials might be beneficial to reduce this learning curve, and further attention to task efficiency could improve user satisfaction. Overall, users expressed a good level of satisfaction with the system. This is a promising result for a mobile-based personalized trip planning application targeting tourists traveling to Thailand. However, addressing the identified areas for improvement could enhance user experience and satisfaction. Future research might investigate the impact of these improvements on user satisfaction and system usability.

TABLE VII.
PSSUQ SCORES

		Mean	SD
SYSUSE	1. Overall, I am satisfied with how easy to use this system.	1.3	0.48
	2. It was simple to use this system.	1.3	0.67
	3. I was able to complete the tasks and scenarios quickly using this system.	1.9	0.88
	4. I felt comfortable using this system.	1.5	0.53
	5. It was easy to learn to use this system.	2	1.83
	6. I believe I could become productive using this system.	1.9	0.74
	Overall SYSUSE	**1.65**	**0.50**
INFOQUAL	7. The system gave error messages that clearly told me how to fix problems.	2.9	1.17
	8. Whenever I made a mistake using the system, I could recover easily and quickly.	2.25	1.09
	9. The information (such as online help, on-screen messages, and other documentation) provided with this system was clear.	2.6	2.12
	10. It was easy to find the information I needed.	1.7	0.82
	11. The information was effective in helping me complete the tasks and scenarios.	1.6	0.84
	12. The organization of information on the system screens was clear.	1.5	0.71
INTERQUAL	**Overall INFOQUAL**	**2.1**	**0.52**
	13. The interface of this system was pleasant.	1.8	0.63
	14. I liked using the interface of this system.	1.6	0.70
	15. This system has all the functions and capabilities I expect it to have.	1.6	0.97
	Overall INTERQUAL	**1.67**	**0.18**
Overall PSSUS	16. Overall, I am satisfied with this system.	1.5	0.70

C. Net Promoter Score

We also looked at the Net Promoter Score (NPS) data, a well-known method to measure how likely users are to suggest a product, service, or system in this study to others. It ranges from -1 to 1, representing a user's total pleasure with the perceived quality of a system. Generally, the NPS contains a single question "On a scale of 0-10, how likely are you to recommend our product/service to a friend or colleague?". Then, the NPS score is calculated based on the user's responses to the question, segmenting into three categories: Promoters (score 9-10), Passives (score 7-8), and Detractors (score 0-6). In this study, the NPS score for 'NimBus' is 0.5 high and favorable. According to this rating, most users are inclined to recommend this system to others, showing signs of excellent user satisfaction and loyalty. It can be found that there were 6 Promoters, 1 Detractor, and 3 Passives when the score was broken down into its components.

Also, the system appears to be well-liked overall, as seen by the relatively high proportion of Promoters compared to Detractors, which is consistent with the high NPS. These Promoters are essential since they are potentially the most devoted users of the system and are more likely to recommend it to others, fostering organic development and useful word-of-mouth promotion. It is noticeable that there are also 3 Passives, though, showing that they are usually content with the system; however, they are not motivated enough to aggressively promote it. They may be susceptible to competitive offerings, as their loyalty is not as solid. It would be beneficial to dig deeper into their feedback and understand what features or improvements might move them into the Promoter category. The existence of a single Detractor indicates that while the system is generally well-received, a small fraction of users have had negative experiences or find the system lacking in some ways (e.g., user experience). This feedback can be valuable for continuous improvement.

In summary, 'NimBus' has successfully generated a positive user experience overall, as evidenced by the NPS of 0.5. However, we should take it a step further by focusing on transforming Passives into Promoters and addressing the concerns of the Detractor. This can be done by maintaining an open communication channel for feedback, refining the user interface and functionality, or adding more personalized features. Moreover, regular usability evaluations should be conducted to keep abreast of changing user perceptions and needs.

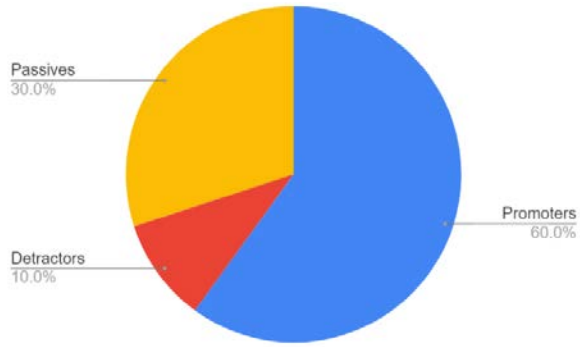


Fig. 24. NPS results

D. Interview Results

The qualitative analysis of the interview data from the usability testing of 'NimBus' yielded a number of insights and helpful criticism. The study has been divided into three categories based on user feedback: user interface design, prospective user interface changes, and additional suggestions for improving the user experience. Users generally agreed in the affirmative about user interface design. Most users commented that the 'NimBus' system was straightforward to use and comprehend for most responders, indicating a user-friendly design. However, opinions about intuitiveness varied. For instance, most users praised the tool's intuitiveness; however, some pointed out a few small places where it might be strengthened.

Regarding future improvements, the criticism was detailed and pointed out interface design elements. Here, the visibility and clarity of specific characteristics were a repeating topic. For example, the "Continue at the end of the page," "Show full schedule button," "View full plan," and "Tags" buttons could all use some user-friendliness and visibility improvements, according to the respondents' feedback. Also, it should be taken into consideration that screen compatibility also became problematic when a user reported a problem with the older version of the iPhone application's user interface. The navigational flow was brought up as another important issue, as suggested by the users. It was noted that the need to leave a

location description to access alternatives should be further improved, implying that changing the navigational structure would enhance the user experience.

Users also offered a variety of comments for further recommendations to improve the user experience. The supply of improved information stood out among these. For example, a user proposed making it possible for users to quickly copy the location's name and specifics so they may conduct more searches on Google and get more data. Another similar idea was to include location photo previews when users hovered over location pins, which may give them a visual indication. One user was perplexed since the tool only displayed sites around Bangkok, highlighting a restriction with the program's geographic coverage. On the plus side, customers acknowledged the tool's ease, its capacity to recommend various sites, and its well-organized and intuitive structure in their reviews. These advantages might be a barometer for future growth and development, such as improved screen compatibility, greater feature visibility, and improved navigational flow. Plan sharing and other tools like image previews might both be implemented. Users have also mentioned the product's ease of use and efficient structure as essential advantages. Enhancing these elements to maintain a positive user experience while making further improvements is important. In addition, they have identified areas that require improvement, specifically regarding feature visibility and navigational flow. Their suggestions include enabling the copying of place data for additional web research, incorporating location photo previews, and expanding geographic coverage. These developments aim to promote the planning process and provide users with a more comprehensive understanding of Thai locations, ultimately fostering more enriching travel experiences. Moreover, they have expressed appreciation for 'NimBus' in its ability to offer a wide range of Thai place recommendations, particularly in the current version's Bangkok area, contributing to diverse tourism opportunities. However, users have a consensus that screen compatibility needs to be enhanced to appeal to a broader audience.

According to user reviews, 'NimBus' is seen as a potential instrument that might increase tourism in Thailand through the wise use of ICT. Most users commented that the system's user-friendliness makes tourists' trip-planning tasks easier and more convenient than existing tools.

> *A user voiced, "Though 'NimBus' streamlines travel planning in Thailand, some aspects need improvements. Enhancing feature visibility and navigation and introducing location photo previews could significantly improve my planning process. It's commendable how it promotes various sites across Thailand, yet addressing the screen compatibility issue could cater to more users. With these modifications, I believe 'NimBus' has the potential to contribute to Thailand's tourism growth."*

In summary, the users think 'NimBus' can encourage growth and variety in Thailand's tourism sector and provide visitors with better services with these ICT-based upgrades based on user input. Based on the qualitative findings, 'NimBus' is praised for being simple to use and comprehend, although there is room for improvement.

VI. DISCUSSION

The usability testing conducted on 'NimBus' offers good evidence in favor of the usability and user-friendliness of digital solutions in enhancing tourists' user experiences and trip organization in Thailand. Also, the findings reveal a positive user perception of 'NimBus,' emphasizing its user-friendly interface, ease of use, and practical features. Thus, it underscores the potential and effectiveness of the system to revolutionize the current tourism industry, particularly in Thailand. Some critical elements distinct from the study's findings include the simplicity of the system's interface design, its well-balanced aesthetics and information organization, and effective navigation design. Generally, using a digital tool or platform to plan a trip may be complicated since it requires integrating extensive information, various visualizations, digital materials (e.g., images and videos), navigation, suggestions, and customization. Users can get frustrated when designing and developing an e-tourism system if the information and navigation are complex, leading to negative user experiences. The findings from the study highlight that it is important to focus on the user's experience and how they interact with the system while considering their specific needs and preferences, especially for systems meant for tourists and travel businesses.

The findings from the SUS and PSSUQ showed that users found the 'NimBus' system easy and simple to use. This indicates that two of our objectives, creating a user-friendly interface and understanding the system's usability and user-friendliness, were accomplished and well-received by the study's participants. The findings also demonstrate the efficacy of our efforts to reduce users' cognitive load by designing an intuitive system. The system's acclaim for user-friendliness can be primarily attributed to the strategic application of established UX principles, including Fitts's Law, as expounded by [40]. Users also found the system neither complex nor inconsistent, suggesting well-integrated features and coherent design, particularly important in the tourism and hospitality sector with diverse and dynamic user needs. Its simplicity indicates potential for real-world adoption. Based on the PSSUQ findings, INFOQUAL scores align with the SUS's results but point to possible error handling and recovery improvements. Users appreciated the system's precise, accessible data – a crucial element for a trip-planning tool.

Ongoing efforts to enhance information quality are thus important. INTERQUAL results also underline user satisfaction with the application's interface. Users enjoyed using the system and found it functionally comprehensive, attesting to its well-designed interface. However, incorporating user feedback for continuous interface optimization could lead to an even more gratifying user experience. The usability test results suggest that 'NimBus' inspires user confidence due to its intuitive navigation and streamlined processes. These also illustrate that the 'design thinking' strategy, applied in this research to develop the digital resource, successfully satisfied crucial user requirements, emphasizing the significance of user interface and experience[11]. This discovery fulfills our objective of assessing the suitability of the 'design thinking methodology, which holds significant relevance for tourism technology.

Furthermore, our tool is well-positioned for wide acceptance and usage among tourists, providing a seamless planning experience. This methodology caters to user needs and has the potential to transform technological engagement, making it more efficient and enjoyable. Also, the usability testing findings for the 'NimBus' system affirm the principles of CogInfoCom by demonstrating how user-centered design enhances tourists' cognitive experiences through ease of use, intuitive learning, and streamlined trip planning. These results underscore the system's capacity to effectively reduce cognitive load, making it a practical and user-friendly tool that aligns well with the CogInfoCom objective of evolving user cognition alongside technological advancements.

The Net Promoter Score (NPS) for our trip planning system, 'NimBus,' underscores user satisfaction, highlights the growth potential, and indicates areas where enhancements can be made. Among our users, the High Promoters demonstrate the system's strengths, the Passives provide valuable insights into areas that need improvement, and the Detractors offer critical feedback. To further improve our system, we aim to refine the interface, incorporate personal touches, maintain open feedback channels, convert Passives into Promoters, and address the issues raised by Detractors. Also, regular reviews will facilitate our system's progression and help us understand its potential in the market. While the results are promising, it's crucial to recognize the variations in user experiences. This diversity reinforces the need for continuous evolution and refinement, as users may exhibit unique needs, preferences, and tech-savvy levels. Such diversity is characteristic of the tourism sector; for instance, tourists visiting Thailand represent many cultural backgrounds and socioeconomic statuses, presenting a broad spectrum of needs and preferences. This underscores the opportunities for the development team to enhance and maintain 'NimBus continually.' Aligning with the 'design thinking' methodology, there's a requisite 'reflection' stage, allowing us to comprehend the accomplished tasks and plan the next steps. This iterative approach helps us to constantly evolve our product, adapting to users' feedback and enhancing the overall user experience.

Despite these positive assessments, users felt the system's ability to recover from mistakes was somewhat lacking, suggesting the need for improved resilience in the system's design. This could be addressed by developing more comprehensive error-handling protocols or automated recovery processes, leading to a more robust and user-friendly platform. However, the slightly higher score for completing tasks quickly and the perceived learning curve suggest room for efficiency enhancement and user guidance. These findings also demonstrate that despite the system's overall usefulness, some users can find it tiresome or time-consuming. To reduce the apparent learning curve and further simplify the user experience, it would be prudent to concentrate on developing features and functionalities that speed up work completion and offer additional guidance or training to users. The findings revealed overall user satisfaction with the system, an encouraging sign that its users perceive it positively. This suggests that the mobile-based personalized trip planning application can potentially bring substantial value to tourists traveling to Thailand by easing their planning process and enhancing their trip experience.

In light of these insights, it is crucial to consider recommendations for further improving the system. Firstly, the tool could be continually updated and refined to accommodate broader user preferences. For instance, by including features like multilingual support and accessibility options, we can reach a wider audience, aligning with e-tourism for local and global tourists. Second, the system is mostly intuitive, given the minimal need for technical support. However, an efficient online help system, like chatbots or an FAQ section, could ensure instant help. This proactive measure can reassure users and encourage continued tool use, even if they encounter minor difficulties. Lastly, the results from the participants who experienced the system as marginal or acceptable suggest there is room for improvement. More studies might be done to comprehend their particular experiences, obstacles, or challenges utilizing technology. This strategy could offer insightful information that can be used to improve the system and eventually improve user experience and performance.

In summary, while our application has shown promise and user satisfaction, the findings highlight specific areas for further research and development. Our application can enhance the tourism experience for international and local tourists traveling in Thailand through a continued refinement and user-focused design. The discussion in this section also has shed light on the potential of using the latest ICTs in Thailand's tourism sector, which is one of our study's objectives. This web-based personalized trip planning tool can potentially ease Thai travel planning for visitors worldwide and locals. The system usability analysis's results show high user satisfaction and the possibility for successful, wide-scale adoption. For sustained efficacy and significance in the evolving tourism sector, the system must be continually enhanced, fine-tuned, and adapted based on user feedback.

The research presented in this paper introduces 'Nimbus,' an innovative interactive web-based personalized trip planning tool designed for tourists in Thailand, which embodies multiple novel contributions to the field of e-tourism. A key innovation is the application of design thinking methodology to the development of the platform, emphasizing empathy, iterative design, and real-world usability, aspects not commonly integrated in digital tourism tools. Additionally, the study unveils a sophisticated algorithm capable of crafting personalized itineraries based on user preferences, local insights, and real-time logistical constraints, such as operational hours and transportation options. This approach not only suggests popular and lesser-known destinations but also effectively balances tourist distribution, thereby supporting under-visited areas. Unlike conventional trip planning tools that often focus on popular tourist sites, 'Nimbus' promotes local inclusivity by highlighting lesser-known attractions and local businesses, thereby fostering a more equitable distribution of economic benefits within the tourism sector. The research rigorously tests the usability of the tool through both qualitative and quantitative methods, ensuring that it meets the practical needs of users and providing a comprehensive analysis of user interaction and satisfaction. Furthermore, the scalability of 'Nimbus' is discussed, highlighting its potential adaptation to other geographical regions or tourism contexts, which underscores

the global applicability of the developed methodologies and technologies. These contributions significantly advance the field of Human-Computer Interaction (HCI) and tourism, offering new perspectives and practical tools for stakeholders in the tourism industry, thereby enhancing both user experience and industry practices.

Based on the quantitative and qualitative findings of the study, the following suggestions are made to further utilize information and communication technology (ICT) for Thailand's tourist industry in light of the study's findings.

- *Continual System Improvements*: Given the dynamic nature of user preferences and rapid technological advancements, it is essential that systems like 'NimBus' undergo regular updates and enhancements. By incorporating user feedback, the platform will be updated with relevant, relevant, and user-friendly technology. This aligns with the 'design thinking' philosophy and its iterative nature.
- *Enhance Customization*: The success of a digital platform depends heavily on customization. We can increase user involvement and satisfaction by including sophisticated features like personalized suggestions based on user preferences or profiles. The study's conclusions suggested how Thailand's tourist sector may better utilize information and communication technology (ICT).
- *Multilingual Support*: Given the nature of globalized tourism, adding multiple language options could improve the system's accessibility for non-English speakers, ultimately expanding its user base.
- *Robust Online Support:* Implementing an effective online support system, like chatbots or an easily navigable FAQ section, will help users resolve issues in real-time, boosting user confidence and satisfaction with the system [25].
- *Security and Privacy Measures:* As digital platforms often involve personal and financial data, it is crucial to implement stringent security measures to protect user information, maintaining trust in the platform.
- *Collaboration with Local Tourism Industry:* Partnering with local tour operators, hotels, restaurants, etc., can provide more accurate and extensive information to tourists, enhancing their overall travel experience in Thailand.

This study opens the door for the burgeoning development of digital technologies in Thailand's tourism sector, offering more efficiency and improved visitor experiences. However, there are some restrictions: our database mainly focuses on Bangkok, our algorithm needs more training, our usability testing sample size is constrained, and our business database needs an extension. Future development will involve expanding our content library, improving personalization, and improving our machine learning algorithm, all of which will increase the usefulness of our digital solution for the tourist industry. The study has several limitations, including a small sample size which may not fully represent the diverse range of tourist preferences, and the preliminary nature of the results which require further validation over an extended timeline and across broader data coverage to ensure the robustness and generalizability of the findings.

VII. CONCLUSION

This research designed a personalized web-based trip planner for tourists visiting Thailand, employing a design thinking methodology. This systematic approach allowed us to understand users' needs, leading to a highly intuitive tool. Our usability assessment, conducted with ten participants, including local and international tourists, indicated that the tool was well-received, with positive feedback. The success of this tool not only emphasizes the potential of Information and Communication Technologies (ICTs) in significantly contributing to tourism sectors worldwide but also suggests a positive impact on local economies reliant on tourism. Furthermore, these promising results invite future exploration into adapting the tool for different tourism types and contexts and integrating advanced features such as real-time updates, reviews, ratings, social sharing, and AI-driven personalized recommendations. In summary, this study highlights the transformative role of ICTs in the tourism sector, pointing to an exciting future for digital solutions in meeting evolving tourist needs and preferences.

VIII. DECLARATION

Conflict of interest: The author(s) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

[1] Asian Development Bank, "Impact of COVID-19 on Thailand's tourism sector," *Asian Development Bank*. [Online]. Available: https://www.adb.org/sites/default/files/linked-documents/54177-001-sd-12.pdf (accessed June 1, 2023).

[2] H. Baier and M.H.M. Winands, "Monte-Carlo Tree Search and minimax hybrids," in P*roceedings of the 2013 IEEE Conference on Computational Intelligence in Games (CIG)*, Niagara Falls, ON, Canada, 2013, pp. 1–8, DOI: 10.1109/CIG.2013.6633630.

[3] A. Bangor, P. Kortum, and J. Miller, "Determining what individual SUS scores mean: Adding an adjective rating scale," *Journal of Usability Studies*, vol. 4, no. 3, pp. 114–123, 2009.

[4] A. Baquero, "Net Promoter Score (NPS) and Customer Satisfaction: Relationship and Efficient Management," *Sustainability*, vol. 14, no. 4, p. 2011, 2022. [Online]. Available: DOI: 10.3390/su14042011.

[5] N. Barawid, "6 technology trends redefining the hospitality industry," *Entrepreneur*, 2022. [Online]. Available: https://www.entrepreneur.com/science-technology/6-technology-trends-redefining-the-hospitality-industry/423654#:~:text=If%20hospitality%20companies%20are%20going,new%20world%20for%20hospitality%20players (accessed June 1, 2023).

[6] A. Basiri, P. Amirian, A. Winstanley, and T. Moore, "Making tourist guidance systems more intelligent, adaptive and personalised using crowd sourced movement data," *Journal of Ambient Intelligence and Humanized Computing*, vol. 9, pp. 413–427, 2018.

[7] BBC, "Covid: Thailand tourism up but still below pre-pandemic level," *BBC*, 2023. [Online]. Available: https://www.bbc.com/news/business-64369279 (accessed June 1, 2023).

[8] M. Blaer, "Interactive webcam travel: supporting wildlife tourism and conservation during COVID-19 lockdowns," *Inf. Technol. Tourism*, vol. 25, pp. 47–69, 2023. [Online]. Available: DOI: 10.1007/s40558-023-00242-3.

[9] D. Buhalis, "Technology in tourism-from information communication technologies to eTourism and smart tourism towards ambient intelligence tourism: a perspective article," *Tourism Review*, vol. 75, no. 1, pp. 267–272, 2019. [Online]. Available: DOI: 10.1108/TR-06-2019-0258.

[10] D. Buhalis, "Technology in tourism-from information communication technologies to eTourism and smart tourism towards ambient intelligence tourism: a perspective article," *Tourism Review*, vol. 75, no. 1, pp. 267–272, 2020. [Online]. Available: DOI: 10.1108/TR-06-2019-0258.

[11] N. Cross, *Design Thinking: Understanding How Designers Think and Work*, 2nd ed. Bloomsbury Visual Arts, 2023.

[12] R. Dam and T. Siang, "What is design thinking and why is it so popular?," *Interaction Design Foundation*, 2022. [Online]. Available: https://www.interaction-design.org/literature/article/what-is-design-thinking-and-why-is-it-so-popular. (accessed June 4, 2023).

[13] Economist Intelligence Unit, "Thailand's tourism industry: adapting to changing times," *Economist Intelligence Unit*, 2022. [Online]. Available: https://www.eiu.com/n/thailand-tourism-industry-adapting-to-changing-times/. (accessed June 1, 2023).

[14] D. A. Guttentag, "Virtual reality: Applications and implications for tourism," *Tourism Management*, vol. 31, no. 5, pp. 637–651, 2010. [Online]. Available: DOI: 10.1016/j.tourman.2009.07.003.

[15] E. Han, "What is design thinking & why is it important?," Harvard Business School Online, 2022. [Online]. Available: https://online.hbs.edu/blog/post/what-is-design-thinking#:~:text=Design%20thinking%20is%20an%20extension,mastered%20through%20practice%20with%20peers. (accessed June 3, 2023).

[16] A. Harley, "Personas make users memorable for product team members," *Nielsen Norman Group*, 2015. [Online]. Available: https://www.nngroup.com/articles/persona/. (accessed June 3, 2023).

[17] Y. C. Huang, K. F. Backman, S. J. Backman, and D. Moore, "Exploring user acceptance of 3D virtual worlds in travel and tourism marketing," *Tourism Management*, vol. 36, pp. 490–501, 2013. [Online]. Available: DOI: 10.1016/j.tourman.2012.09.009.

[18] Igor, "IoT smart hotels: Enabling innovation in the hospitality industry," *Igor*, 2020. [Online]. Available: https://www.igor-tech.com/news-and-insights/articles/iot-smart-hotels-enabling-innovation-in-the-hospitality-industry#:~:text=In%20an%20IoT%20smart%20hotel,keep%20smart%20hotels%20running%20efficiently. (accessed June 1, 2023).

[19] International Monetary Fund, "Five things to know about Thailand's economy and COVID-19," *International Monetary Fund*, 2021. [Online]. Available: https://www.imf.org/en/News/Articles/2021/06/21/na062121-5-things-to-know-about-thailands-economy-and-covid-19. (accessed June 1, 2023).

[20] Y. Jeaheng and H. Han, "Thai street food in the fast-growing global food tourism industry: Preference and behaviors of food tourists," *Journal of Hospitality and Tourism Management*, vol. 45, pp. 641–655, 2020.

[21] M. Lewrick, P. Link, and L. Leifer, The Design Thinking Toolbox: A Guide to Mastering the Most Popular and Valuable Innovation Methods (Design Thinking Series), 1st ed. Wiley, 2020.

[22] K. H. Lim, J. Chan, S. Karunasekera, and C. Leckie, "Personalized itinerary recommendation with queuing time awareness," in *Proceedings of the 40th International ACM SIGIR Conference on Research and Development in Information Retrieval*, pp. 325–334, 2017. [Online]. Available: DOI: 10.1145/3077136.3080778.

[23] X. Liu, F. Mehraliyev, C. Liu, and M. Schuckert, "The roles of social media in tourists' choices of travel components," *Tourist Studies,* vol. 20, no. 1, pp. 27–48, 2020. [Online]. Available: DOI: 10.1177/1468797619873107.

[24] R. Logesh, V. Subramaniyaswamy, V. Vijayakumar, and X. Li, "Efficient user profiling based intelligent travel recommender system for individual and group users," *Mobile Netw Appl*, vol. 24, pp. 1018–1033, 2019. [Online]. Available: DOI: 10.1007/s11036-018-1059-2.

[25] L. Mich and R. Garigliano, "ChatGPT for e-Tourism: a technological perspective," *Inf. Technol. Tourism*, vol. 25, pp. 1–12, 2023. [Online]. Available: DOI: 10.1007/s40558-023-00248-x.

[26] Ministry of Tourism and Sports, "Tourist statistics," *Ministry of Tourism and Sports*, 2023. [Online]. Available: https://www.mots.go.th/news/category/411. (accessed May 31, 2023).

[27] B. Neuhofer, D. Buhalis, and A. Ladkin, "A typology of technology-enhanced tourism experiences," *International Journal of Tourism Research*, vol. 16, no. 4, pp. 340–350, 2013. [Online]. Available: DOI: 10.1002/jtr.1958.

[28] T. Pencarelli, "The digital revolution in the travel and tourism industry," *Inf. Technol. Tourism*, vol. 22, pp. 455–476, 2020. [Online]. Available: DOI: 10.1007/s40558-019-00160-3.

[29] P. Penfold, "Learning through the world of second life—A hospitality and tourism experience," *Journal of Teaching in Travel & Tourism*, vol. 8, no. 2-3, pp. 139–160, 2009. [Online]. Available: DOI: 10.1080/15313220802634224.

[30] S. Pongsakornrungsilp, P. Pongsakornrungsilp, V. Kumar, and B. Maswongssa, "The art of survival: Tourism businesses in Thailand recovering from COVID-19 through brand management," *Sustainability*, vol. 13, p. 6690, 2021. [Online]. Available: DOI: 10.3390/su13126690.

[31] J. Rubin and D. Chisnell, *Handbook of Usability Testing: How to Plan, Design, and Conduct Effective Tests*, 2nd ed. Wiley, 2008.

[32] T. Sanglee, "China's 'Zero-COVID' policy: An economic nightmare for Thailand," *The Diplomat*, 2022. [Online]. Available: https://thediplomat.com/2022/10/chinas-zero-covid-policy-an-economic-nightmare-for-thailand/. (accessed June 1, 2023).

[33] J. Sauro, "Measuring usability with the system usability scale (SUS)," *MeasuringU*, 2011. [Online]. Available: https://measuringu.com/sus/. (accessed June 4, 2023).

[34] J. Sauro, "10 things to know about the post study system usability questionnaire," *MeasuringU*, 2019. [Online]. Available: https://measuringu.com/pssuq/. (accessed June 4, 2023).

[35] S. Saxon, J. Sodprasert, and V. Sucharitakul, "Reimagining travel: Thailand tourism after the COVID-19 pandemic," *McKinsey & Company*, 2021. [Online]. Available: https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/reimagining-travel-thailand-tourism-after-the-covid-19-pandemic. (accessed May 31, 2023).

[36] Siam Commercial Bank, "Thailand After COVID-19 Pandemic," *Siam Commercial Bank*, 2022. [Online]. Available: https://www.scb.co.th/en/personal-banking/stories/business-maker/thailand-after-covid-ep2.html. (accessed June 1, 2023).

[37] Tourism Authority of Thailand, "Thailand named among top 3 best countries in the world by readers of Condé Nast Traveler," *Tourism Authority of Thailand*, 2022. [Online]. Available: https://www.tatnews.org/2022/10/thailand-named-among-top-3-best-countries-in-the-world-by-readers-of-conde-nast-traveler/. (accessed May 31, 2023).

[38] United Nations, "Thailand Economic Focus: Thailand plunges into recession as COVID-19 hits tourism and its related industries," *United Nations*, 2020. [Online]. Available: https://thailand.un.org/en/50918-thailand-economic-focus-thailand-plunges-recession-covid-19-hits-tourism-and-its-related. (accessed June 1, 2023).

[39] Z. Xiang, D. Wang, J. T. O'Leary, and D. R. Fesenmaier, "Adapting to the Internet: Trends in travelers' use of the web for trip planning," *Journal of Travel Research*, vol. 54, no. 4, pp. 511–527, 2015. DOI: 10.1177/0047287514522883

[40] J. Yablonski, P*Laws of UX: Using Psychology to Design Better Products & Services*, 1st ed. O'Reilly Media, 2020.

[41] A. Pyae, "Can a location-based game make players mindful during the gameplay? A case study of Pokémon GO," *Int. J. Netw. Virtual Organisations*, vol. 27, no. 4, pp. 319–336, 2023. [Online]. Available: DOI: 10.1504/IJNVO.2022.130945.

[42] R. Yung, C. Khoo-Lattimore, and L.-E. Potter, "VR the world: Experimenting with emotion and presence for tourism marketing," *Journal of Hospitality and Tourism Management*, vol. 46, pp. 160–171, 2021. [Online]. Available: DOI: 10.1016/j.jhtm.2020.11.009.

[43] B. Zeng and R. Gerritsen, "What do we know about social media in tourism? A review," *Tourism Management Perspectives,* vol. 10, pp. 27–36, 2014. [Online]. Available: DOI: 10.1016/j.tmp.2014.01.001.

[44] R. Zivkovic, J. Gajic, and I. Brdar, "The Impact of social media on tourism," in *The Impact of Internet on Business Activities in Serbia and Worldwide Conference*, Serbia, 2014, pp. 758–761.

[45] A-A. Berger, *Thailand Tourism*. Taylor & Francis, UK, 2014.

[46] P. Baranyi, A. Csapó, and G. Sallai, "Definitions, Concepts, and Assumptions, " In: *Cognitive Infocommunications (CogInfoCom)*. Springer, Cham, 2015, DOI: 10.1007/978-3-319-19608-4_2

[47] P. Baranyi and A. Csapó, "Definition and synergies of cognitive infocommunications," *Acta Polytechnica Hungarica*, vol. 9, no. 1, pp. 67–83, 2012.

[48] A. Pyae, M. Luimula, and J. Smed, "Investigating the usability of interactive physical activity games for elderly: A pilot study," *2015 6th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, 2015, pp. 185–193, DOI: 10.1109/CogInfoCom.2015.7390588.

[49] P. Markopoulos, A. Pyae, J. Khakurel, E. Markopoulos, R. Saarnio, and M. Luimula, "Understanding How Users Engage in an Immersive Virtual Reality-Based Live Event, " In: *Proceedings of the 12th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, 2021, pp. 881–899.

[50] A. Pyae, M. Luimula, and Patanothai, C, "Investigating User's Engagement and Enjoyment in Immersive Virtual Reality-Based Exercises: An Exploratory Study, " In *Proceedings of the 12th IEEE International Conference on Cognitive Infocommunications 2021,* pp. 471–477.

[51] A. Esposito, G. Cordasco, C. Vogel, and P. Baranyi, "Editorial: Cognitive infocommunications," *Front. Comput. Sci.*, vol. 5, no. 1129898, 2023. DOI: 10.3389/fcomp.2023.1129898.

Tiparpa Soongswang Currently employed as a Senior Associate at a leading telecommunications and digital services provider in Thailand. She works as a project owner, driving initiatives to improve internal business processes across multiple areas, including sales pipeline management, billing, and sales reinforcement. Her professional interests lie in customer experience and process improvement, where she enjoys combining business insights with technology to deliver impactful results.

Kawin Srisilpavongse is a former ICE student at the International School of Engineering, Faculty of Engineering, Chulalongkorn University.

Kritawat Kraiwitchaocharoen Currently employed as a Data Engineer at Egg Digital, working across diverse domains including data modeling, data warehousing, data pipeline development, cloud computing, and DevOps for data operations in the retail industry for both Thailand and Malaysia. Passionate about designing and building scalable, reliable, and high-performance data infrastructures. His interests are in the evolving field of data engineering where the fusion of technology, automation, and analytics enable organizations to unlock the full potential of their data.

Kiartnarin Udomlapsakul is a former ICE student at the International School of Engineering, Faculty of Engineering, Chulalongkorn University.

Nuttayos Charukulvanich is a former ICE student at the International School of Engineering, Faculty of Engineering, Chulalongkorn University.

Kritchavit Thippayajindakul is a former ICE student at the International School of Engineering, Faculty of Engineering, Chulalongkorn University.

Nattakit Pisitsup Currently employed as a software developer at Playtorium Solutions, working across both frontend and backend development with a particular focus on frontend engineering. He is passionate about web and mobile application development, creating intuitive and engaging user experiences. Nattakit has contributed to projects for several high-profile companies in Thailand, gaining valuable experience in building real-world applications.

Burapa Chinwatanakit is a former ICE student at the International School of Engineering, Faculty of Engineering, Chulalongkorn University.

Maia Kawamura is a former ICE student at the International School of Engineering, Faculty of Engineering, Chulalongkorn University.

Mathis Person is a former ICE student at the International School of Engineering, Faculty of Engineering, Chulalongkorn University.

Napatra Navanugraha Currently employed as a Software engineer at Bangkok Bank Public Company Limited, with a focus on user identity access management (IAM) for software systems. His interests are in the domain of software security, enterprise-level design and architectural solutions for scalable and robust infrastructures.

Tai Tienboon is a former ICE student at the International School of Engineering, Faculty of Engineering, Chulalongkorn University.

Natdanai Aramrueng is a former ICE student at the International School of Engineering, Faculty of Engineering, Chulalongkorn University.

Chawin Sungkhapong Currently employed as a DevOps engineer at Siam Commercial Bank, driving support for the migration of the Core Banking System from legacy mainframe to cloud microservices. His work encompasses cloud administration, CICD implementation, IaC module development, task automation, and cost optimization. His personal interests include security and UX/UI design.

Gevalin Wongweerakit is a former ICE student at the International School of Engineering, Faculty of Engineering, Chulalongkorn University.

Aung Pyae Currently serving as a full-time lecturer at the International School of Engineering (ISE), within the Faculty of Engineering at Chulalongkorn University in Bangkok, Thailand, Dr. Aung Pyae is actively engaged in the field of human-computer interaction (HCI). His research interests include user interface design, user experience, and human-centered AI. Dr. Pyae is currently exploring the HCI aspects of emerging technologies such as the Metaverse, health applications, and voice user interfaces. He has published over 70 papers in international peer-reviewed journals and conferences, primarily as the main author, and has been an invited speaker at various academic events. His work is documented through publications in international peer-reviewed journals and HCI-focused conferences.

Guidelines for our Authors

Format of the manuscripts

Original manuscripts and final versions of papers should be submitted in IEEE format according to the formatting instructions available on

https://journals.ieeeauthorcenter.ieee.org/
Then click: "IEEE Author Tools for Journals"
- "Article Templates"
- "Templates for Transactions".

Length of the manuscripts

The length of papers in the aforementioned format should be 6-8 journal pages.
Wherever appropriate, include 1-2 figures or tables per journal page.

Paper structure

Papers should follow the standard structure, consisting of *Introduction* (the part of paper numbered by "1"), and *Conclusion* (the last numbered part) and several *Sections* in between.
The Introduction should introduce the topic, tell why the subject of the paper is important, summarize the state of the art with references to existing works and underline the main innovative results of the paper. The Introduction should conclude with outlining the structure of the paper.

Accompanying parts

Papers should be accompanied by an *Abstract* and a few *Index Terms (Keywords)*. For the final version of accepted papers, please send the short cvs and *photos* of the authors as well.

Authors

In the title of the paper, authors are listed in the order given in the submitted manuscript. Their full affiliations and e-mail addresses will be given in a footnote on the first page as shown in the template. No degrees or other titles of the authors are given. Memberships of IEEE, HTE and other professional societies will be indicated so please supply this information. When submitting the manuscript, one of the authors should be indicated as corresponding author providing his/her postal address, fax number and telephone number for eventual correspondence and communication with the Editorial Board.

References

References should be listed at the end of the paper in the IEEE format, see below:

a) Last name of author or authors and first name or initials, or name of organization
b) Title of article in quotation marks
c) Title of periodical in full and set in italics
d) Volume, number, and, if available, part
e) First and last pages of article
f) Date of issue
g) Document Object Identifier (DOI)

[11] Boggs, S.A. and Fujimoto, N., "Techniques and instrumentation for measurement of transients in gas-insulated switchgear," IEEE Transactions on Electrical Installation, vol. ET-19, no. 2, pp.87–92, April 1984. DOI: 10.1109/TEI.1984.298778

Format of a book reference:

[26] Peck, R.B., Hanson, W.E., and Thornburn, T.H., Foundation Engineering, 2nd ed. New York: McGraw-Hill, 1972, pp.230–292.

All references should be referred by the corresponding numbers in the text.

Figures

Figures should be black-and-white, clear, and drawn by the authors. Do not use figures or pictures downloaded from the Internet. Figures and pictures should be submitted also as separate files. Captions are obligatory. Within the text, references should be made by figure numbers, e.g. "see Fig. 2."
When using figures from other printed materials, exact references and note on copyright should be included. Obtaining the copyright is the responsibility of authors.

Contact address

Authors are requested to submit their papers electronically via the following portal address:

https://www.ojs.hte.hu/infocommunications_journal/about/submissions

If you have any question about the journal or the submission process, please do not hesitate to contact us via e-mail:

Editor-in-Chief: Pál Varga – pvarga@tmit.bme.hu

Associate Editor-in-Chief:

József Bíró – biro@tmit.bme.hu

László Bacsárdi – bacsardi@hit.bme.hu

IEEE/IFIP Network Operations and Management Symposium
18 - 22 May 2026 // Rome, Italy
AI for Management and Management for AI

CALL FOR PAPERS

The 2026 IEEE/IFIP Network Operations and Management Symposium (NOMS 2026) will be held 18–22 May 2026, in Rome, Italy. First organized in 1988, NOMS follows the 38-year tradition of NOMS and IM as the IEEE Communications Society's primary forum for technical exchange on network and service management, focusing on research, development, integration, standards, service provisioning, and user communities. Under the theme **"AI for Management and Management for AI"**, NOMS 2026 seeks original contributions that address recent developments and technical solutions for the management of emerging and future networks and services. The theme emphasizes the dual role of artificial intelligence: as a driver empowering network and service management, and as a workload that demands reliable, scalable, and sustainable infrastructures. The NOMS 2026 program will feature a rich set of sessions, including keynotes, tutorials, technical sessions, experience sessions, demos, posters, panels, and dissertation sessions.

Management of Networks
- IP Networks
- Wireless and Cellular Networks
- 5G network and Beyond (6G)
- Quantum Networks
- Optical Networks
- Virtual Networks and SDN
- Home and Access Networks
- Fog, Edge and Cloud Networks
- Enterprise and Campus Networks
- Data Center Networks
- Industrial Networks
- Vehicular and Autonomous Systems Networks
- IoT, Sensor and M2M Networks
- Information-Centric Networks
- Mission Critical Networks

Management of Services
- Multimedia and Immersive Media Services
- Over-The-Top Services
- Content Delivery Services
- Cloud Computing, Edge Services, and Computing Continuum
- Internet Connectivity and Internet Access Services
- Internet of Things Services
- Security and Privacy Services
- Context-Aware Services
- Information Technology Services
- Service Assurance
- Management of AI Workloads and Services

Management of Businesses
- Economic Aspects
- Multi-Stakeholder Aspects
- Service Level Agreements
- Lifecycle, Process, and Workflow Management
- Legal, Regulatory, and Compliance Perspectives
- Privacy Aspects
- Organizational Aspects

Functional Areas
- Fault Management
- Configuration Management
- Accounting Management
- Performance Management
- Security Management

Management Paradigms
- Centralized, Hierarchical and Distributed Management
- Integrated Management
- Federated Management
- Autonomic and Cognitive Management
- Policy- and Intent-Based Management
- Model-Driven Management
- Proactive Management
- Energy-aware Management
- QoE-Centric Management
- Zero-Touch and Self-Driving Networks

Management Technologies
- Communication Protocols
- Middleware
- Overlay and Peer-to-Peer Networks
- Cloud Computing and Cloud Storage
- Data, Information, and Semantic Models
- Information Visualization
- Software-Defined Networking
- Network Function Virtualization
- Orchestration
- Operations and Business Support Systems
- Control and Data Plane Programmability
- Distributed Ledger Technology
- Digital Twins
- Programmable and AI-Driven Network Architectures
- AI-based management (Reinforcement Learning, Generative AI, ...)

Methods
- Mathematical Logic and Automated Reasoning
- Optimization Theories
- Control Theory
- Probability Theory, Stochastic Processes, Queuing Theory
- Artificial Intelligence and Machine Learning
- Evolutionary Algorithms
- Economic Theory, Game Theory and Business Models
- Risk Management Methods
- Monitoring and Measurements
- Data Mining and (Big) Data Analysis
- Computer Simulation Experiments
- Testbed Experimentation and Field Trials
- Software Engineering Methodologies

Authors are invited to submit original contributions that advance the state of the art in network and service management. Submissions should emphasize both novelty and impact, supported by theoretical analysis, simulations, testbeds, or real-world deployments.

IMPORTANT DATES:

Paper Submission:
October 27, 2025 *(Extended)*

Notification of Acceptance:
January 18, 2026

Camera Ready Paper:
February 14, 2026

GENERAL CO-CHAIRS:

Pierpaolo Loreti
University of Rome Tor Vergata, Italy

Eiji Oki
Kyoto University, Japan

TPC CO-CHAIRS:

Lorenzo Bracciale
University of Rome Tor Vergata, Italy

Marc-Oliver Pahl
IMT Atlantique, France

Carlos Raniery Paula dos Santos
Federal University of Santa Maria, Brazil

https://noms2026.ieee-noms.org/

SCIENTIFIC ASSOCIATION FOR INFOCOMMUNICATIONS

Who we are

Founded in 1949, the Scientific Association for Infocommunications (formerly known as Scientific Society for Telecommunications) is a voluntary and autonomous professional society of engineers and economists, researchers and businessmen, managers and educational, regulatory and other professionals working in the fields of telecommunications, broadcasting, electronics, information and media technologies in Hungary.

Besides its 1000 individual members, the Scientific Association for Infocommunications (in Hungarian: HÍRKÖZLÉSI ÉS INFORMATIKAI TUDOMÁNYOS EGYESÜLET, HTE) has more than 60 corporate members as well. Among them there are large companies and small-and-medium enterprises with industrial, trade, service-providing, research and development activities, as well as educational institutions and research centers.

HTE is a Sister Society of the Institute of Electrical and Electronics Engineers, Inc. (IEEE) and the IEEE Communications Society.

What we do

HTE has a broad range of activities that aim to promote the convergence of information and communication technologies and the deployment of synergic applications and services, to broaden the knowledge and skills of our members, to facilitate the exchange of ideas and experiences, as well as to integrate and harmonize the professional opinions and standpoints derived from various group interests and market dynamics.

To achieve these goals, we…

- contribute to the analysis of technical, economic, and social questions related to our field of competence, and forward the synthesized opinion of our experts to scientific, legislative, industrial and educational organizations and institutions;
- follow the national and international trends and results related to our field of competence, foster the professional and business relations between foreign and Hungarian companies and institutes;
- organize an extensive range of lectures, seminars, debates, conferences, exhibitions, company presentations, and club events in order to transfer and deploy scientific, technical and economic knowledge and skills;
- promote professional secondary and higher education and take active part in the development of professional education, teaching and training;
- establish and maintain relations with other domestic and foreign fellow associations, IEEE sister societies;
- award prizes for outstanding scientific, educational, managerial, commercial and/or societal activities and achievements in the fields of infocommunication.

Contact information

President: **FERENC VÁGUJHELYI** • *elnok@hte.hu*

Secretary-General: **GÁBOR KOLLÁTH** • *kollath.gabor@hte.hu*

Operations Director: **PÉTER NAGY** • *nagy.peter@hte.hu*

Address: H-1051 Budapest, Bajcsy-Zsilinszky str. 12, HUNGARY, Room: 502

Phone: +36 1 353 1027

E-mail: *info@hte.hu*, Web: *www.hte.hu*