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Review of the doctoral thesis of Mr Paweł
Gwiaździński, M.Sc. „Unseen Potential: Advancing
Sensory Substitution Devices with Human-Centered
User Experience Approach
(Niewidoczny potencjał: Rozwój urządzeń do
substytucji sensorycznej z wykorzystaniem podejścia
Human-Centered User Experience)”

1 Formal requirements

I received the dissertation in hard copy and in electronic form, identical to the hard copy. The dissertation contains an abstract in English and Polish (pp. 7-8 and 9-10). Thus, the formal requirements set out in Article 187 of the Act of 20 July 2018. - Law on Higher Education and Science (i.e. Journal of Laws of 2023, item 742, as amended) are met.

Page numbers in brackets refer to the page numbers of the dissertation submitted for review.

According to the information received 3rd April 2024 from the Council of the Discipline of Psychology, the doctoral dissertation of Mr Paweł Gwiaździński - according to his declaration - is a written work in typescript form. The recommendations of the Council of the Psychology Discipline of the Jagiellonian University concerning doctoral dissertations (Appendix to resolution no. 4 /IV/2021 of 8 April 2021) for this type of doctoral thesis are met.

The Author has included the following papers in the dissertation:

- Conference proceedings: Bizoń P. et al, "VIRCO: A virtual reality tool for long-term training and evaluation of the cognitive skills development in an interactive sensory

substitution environment," 2019 Joint IEEE 9th International Conference on Development and Learning and Epigenetic Robotics (ICDL-EpiRob), Oslo, Norway, 2019, pp. 87-92, doi: 10.1109/DEVLRN.2019.8850696.

The manuscript is multi-authored (11 authors) and the Author is listed as second author.

- Material deposited in the SSRN repository: Lukowska M. et al., Better act than see: individual differences in sensorimotor contingencies acquisition and (meta)cognitive strategies between users of a colour-to-sound sensory substitution device (June 29, 2021). Available at SSRN: <https://ssrn.com/abstract=4113324> or <http://dx.doi.org/10.2139/ssrn.4113324>

The paper is multi-authored and the Author is listed as second author, however this paper is not a scientific article. It is a non-peer-reviewed preprint posted in the publicly available Social Science Research Network repository.

- Material posted in the SSRN repository: Gwiazdziński P. et al., Research protocol. Usability of Sensory Substitution systems: test and comparison of BrainPort and Colorophone devices (July 18, 2022). Available at SSRN: <https://ssrn.com/abstract=4165732> or <http://dx.doi.org/10.2139/ssrn.4165732>.

The paper is multi-authored and the Author is first author, however this paper is not a scientific article. It is a non-peer-reviewed preprint posted in the publicly available Social Science Research Network repository.

In the dissertation, the Author included a description of the contribution of all authors to the publications (p. 32, 43, 56). After my enquiry, the contribution information was completed by the Author (e-mail of 9th April 2024).

2 Evaluation of the doctoral dissertation

According to Article 187 of the Act of 20 July 2018. - Law on Higher Education and Science:

1. The doctoral dissertation presents the candidate's general theoretical knowledge in the discipline or disciplines and the ability to conduct scientific or artistic work independently.
2. The subject of a doctoral dissertation shall be an original solution to a scientific problem, an original solution to the application of the results of one's scientific research in the economic or social sphere or an original artistic achievement.

Using this legal basis, I assessed in the review successively the relevance and significance of the chosen research problem, the way in which the candidate presents his knowledge and the ability to conduct scientific work independently, and the level of originality the solution of scientific problem.



2.1 The overview of the doctoral dissertation

Chapter I introduces the idea of Sensory Substitution (SS), the review of the most popular SSD for vision substitution, the challenges including usability and training issues. Finally, in the Overview (p. 31) Author describes studies presented in the dissertation.

Chapter II focus on two studies made with usage Virtual Reality Cognitive Training System (VIRCO) for visual-to-auditory device users training. The first study was made with 16 sighted-blindfolded participants (10 results taken into account). Its aim was to assess the accuracy of Colorophone (CLRP) system for color and shape recognition and users' satisfaction after 3 days of training with usage VIRCO. The second longitudinal study was made with 18 sighted-blindfolded participants (16 results analyzed). The test procedure included VIRCO trainings and laboratory tasks. This study had many aims, however in the dissertation results in the accuracy of Colorophone system for color and shape recognition and users' satisfaction after 12 weeks (36 hours) of training are presented. Additionally, different learning strategies and their influence on participants' performance are discussed (pp. 53-54). In summary, the research shows the potential of the CLRP, highlights the importance of training, and underscores VIRCO's role as a valuable tool for SSD skills development.

Chapter III presents usability tests comparing two SSDs: visual-to-tactile device BrainPort Vision Pro (BP) and visual-to-auditory device Colorophone (CLRP) system. Tests were followed by 10 days training and included typical daily routine tasks at home and outdoor. Seven blind participants took part in the tests, including 3 in the pilot study and 4 in the main study. Results were analyzed according to ISO 9241:11:2018 standard in three dimensions: effectiveness, efficiency and users' satisfaction, including rich qualitative analysis.

In the final part of the dissertation (Chapter IV), the Author considers the results of studies described in Chapter II and III. He underlined the social and esthetic aspects of SSDs, the meaning of individual preferences, the role of proper training design and the availability of SSDs. He proposes seven guidelines to improve User Experience (UX) of SSDs.

2.2 The relevance and significance of the chosen research problem

The author declares the following aim: „The overarching goal of this work is investigation of the usability research to the field of sensory substitution (SS), while putting human needs of people living with disabilities in the centre (p. 7)”. To achieve the goal, the Author presents the results of several usability studies of different sensory substitution devices (SSD). SSDs are technological devices that aim to compensate for the loss or impairment of one sensory modality (in this case vision) by conveying information through another sensory channel. The main principle of SSD is cross-modal plasticity, which means that the brain can adapt and process information from one sensory modality using another. Users with special needs are often overlooked in the interaction design process. Therefore, the discussed topic is significant, and involving SS users (people with disabilities) in the design and testing process of technologies intended for them is highly desirable. **The problem addressed by the Author**



is of significant importance in the field of Human-Computer Interaction (HCI) and the choice of dissertation topic is fully justified.

2.3 Evaluation of theoretical knowledge presented in the doctoral thesis

The main part of theoretical background is presented in the Chapter I. However, this is not very complex and comprehensive. Particularly notable here is the lack of two papers:

1. ISO 9241-210:2019 Ergonomics of human-system interaction Part 210: Human-centred design for interactive systems – standard provides, among other things, an overview of human-centred design activities, including iterative testing with users
2. International Classification of Functioning, disability and health (ICF) (2001) – ICF provides a new approach to disability. It replaces the medical approach, which is geared towards the assessment of dysfunctions caused by a health condition, with a social approach, in which the way in which the individual carries out activities in the environment is key. Although the Author mentions the medical model in the dissertation (p. 24), he does not refer to it. Especially in Chapter IV such a reference would have been necessary.

The Author's omission of relevant literature items in the theoretical part results in trivialisation of the recommendations formulated in the conclusion of the work. Below are some examples of unused publications that seem to me to be relevant to the topic of the thesis:

1. (Stronks et al., 2015) – provides an overview of the SSD technology for VIP including the substitution technique used;
2. (Kristjánsson et al., 2016) – provides recommendations in the area of SSD technology design for VIPs taking into account usability and how information is perceived;
3. (Lloyd-Esenkaya et al., 2020) - provides, among other things, an overview of cognitive tasks performed effectively with visual-tactile or visual-auditory sensory substitution technologies, an analysis of the reasons for the low popularity of these technologies, and a compilation of recommendations for the design of inclusive multimodal interfaces;
4. (Maidenbaum et al., 2014) – provides, among other things, an overview of approaches to the use of SSDs for VIP support, particularly in the context of rehabilitation and training opportunities. Among other things, the publication analyses the learning process and the potential of using SSD for VIP;
5. ISO 9241-20:2021 Ergonomics of human-system interaction Part 20: An ergonomic approach to accessibility – provides the information about the importance of accessibility to human-system interaction and a discussion of the relationship of principles within the ISO 9241 series and accessibility;
6. Publications evaluating applications for people with visual impairments:

- a. (Kuriakose et al., 2022) – provides an overview of technologies supporting VIP navigation and design recommendations, including the problem of social stigma raised by the Author in the dissertation;
- b. (Hussain & Omar, 2020) - provides a Systematic Literature Review (SLR) to identify usability dimensions to evaluate mobile application for VIP. The authors identified 6 main dimensions: efficiency, effectiveness, satisfaction, errors, accessibility and understandability;
- c. (Järvelä et al., 2022) – contains the results of a pilot survey of VIPs in Finland, but the results in terms of VIP behaviour towards the application may inspire the Author.

Summarizing, **the Author presented the general knowledge in the dissertation**, however a more in-depth literature review would have allowed more in-depth conclusions to be drawn in the research.

2.4 Evaluation of ability to carry out scientific work independently presented in the doctoral thesis

I had troubles to assess the Author's ability to carry out scientific work independently is due to the multi-author papers included to the dissertation. However, after the additional information about the individual contribution of Author to all the presented research, I was more likely to evaluate this issue. According to the Author's declaration, I relied most extensively on the research described in Chapter III, because here the author's individual contribution was most apparent.

This study was carried out in accordance with the usability testing procedure with users. I also appreciate such a lengthy research procedure to really assess the user's interaction with the technology. However, my doubt is whether the study presented is a comparison of two SSDs, i.e. CPLRP and BP, or two SS, i.e. visual-to-tactile and visual-to-auditory. Most of the Authors analysis of test participants satisfaction (pp. 79-86) comments different sensory substitution approach, not a specific devices compared in the research.

My another comment is about the way of results presenting. With such small samples, it would be useful to approach the analysis of the results in a qualitative way and describe them individually for each participant. At the same time, the results cannot be generalized. The sentence "There were no clear patterns in terms of age, sex, education, duration of blindness, or reported memory of colours that could explain differences in usability ratings" (p. 73) is inappropriate, as it suggests for four participants statistical analysis is possible.

The number of participants in the research, although small, is sufficient to draw conclusions about the usability of the investigated systems, in line with the research results cited by the Author (p. 25). However, I am not convinced that it is possible to assess e.g. learning patterns on this basis. It is also questionable to conduct statistical analyses based on such small



samples i.e. N=16 (Table 3 and 4, pp. 51-52). However, the sample size is understandable as the Author is studying a niche environment.

The Author ignores most of the limitations of the studies discussed, which significantly affects my evaluation of the dissertation. All studies were conducted on visual-to-tactile or visual-to-auditory SSDs. In my opinion, they cannot be generalized to other SSDs i.e. auditory-to-visual that can be used by, for example, deaf or low hearing people. Their ways of interacting with the environment and technology are different. The Author should take this issue into account in the title of the dissertation.

In Table 16 Author compares various applications used by study participants as supportive aids, but the main idea of BeMyEyes (network of volunteers supporting users with low vision with users' camera) is quite different than other apps and should be presented in the comparison.

In summary, the **Author has demonstrated his ability to plan, conduct, describe and verify a multi-stage research project**. Despite the imperfections noted, I conclude that the studies was carried out correctly, although the Author's criticism of his research and the conclusions drawn from it is necessary.

2.5 Evaluation of the originality of the solution to the scientific problem

As I mentioned above, the scientific problem is important and original. The set of research conducted with the Author participation brings new knowledge in the area of HCI, especially in context of visually impaired users. This applies both to the way usability testing is carried out and to user training. In contrast, the key guidelines formulated in the final part of the paper do not, in my opinion, constitute a significantly new solution to the scientific problem.

In conclusion, **the level of originality of the presented solution to the scientific problem is sufficient**.

3 Formal evaluation of the dissertation

I carried out a formal evaluation of the dissertation taking into account the composition, bibliography, and editing.

3.1 Composition

The structure of the dissertation is not very clear, lacking a discussion of the aim of the doctoral thesis at the beginning and a reference to this aim at the end of the paper. Information about the aims of the work, the applied methods and approaches are scattered throughout the paper (i.e. pp. 14, 24-25, 31, 53, 55, 93, 99) and it is difficult to follow the Author's reasoning.

Perhaps it would be helpful to present in the context of the main aim of the dissertation the aims of all the research included as well as their main tools, methods and participants

characteristics. The visualization of the research process and conclusion formulation would be helpful. There is a lack of conclusion in the dissertation - recommendations presented in the final section are insufficient.

3.2 Editing

The dissertation has been prepared with editorial and formal care. It contains correct footnotes, captions of tables and figures, references to bibliographic items, references to tables and figures and tables. This demonstrates the Author's ability of writing scientific publications.

A glossary of terms and abbreviations used in the dissertation, placed at the beginning or at the end of the paper, would be a great help in reading the dissertation. With this number of abbreviations occurring in the dissertation, a glossary of abbreviations would have been useful. In addition, the Author often does not complete the good practice of defining an abbreviation when first used (i.e. System Usability Scale, first usage p. 62), for this reason a glossary would be a useful support for the reader.

Other editorial remarks:

- **Terminological issues:**
 - **Visually impaired persons (VIP)** – if I understood well, the Author counts into this group blind persons only. However, in the literature, it is a broader term to mean people with visual impairments, including blind people (National Centre on Disability and Journalism, 2021), (Kuriakose et al., 2022);
 - Use of the name **System Usability Survey** (p. 62, 68, 71 - subchapter title) - the correct name of the tool is System Usability Scale, abbreviated SUS;
 - **Accessibility versus availability** (p. 99) – in Polish language both terms are described in the same word (“dostępność”). In English, accessibility can be used in both contexts, however the good practice is to divide both meanings by using accessibility as ability to access (especially for those with special needs) and availability as ability of being used or seen.
- **Repeated text fragments**, e.g. first paragraph p.13, reference Łukowska, M., Osiński, D., Ciupińska, K., Hat, K., Gwiaździński, P., Hviid del Pin, S., Kałwak, W., Korczyk, M., Bizoń-Angov, P., Reuter, M., Szwed, M., & Wierzchoń, M. (2021). *Better act than see: Individual differences in sensorimotor contingencies acquisition and (meta)cognitive strategies between users of a colour-to-sound sensory substitution device* (SSRN Scholarly Paper 4113324). <https://doi.org/10.2139/ssrn.4113324> (p. 110);
- **Some errors in bibliographical descriptions in References**, ie.:
 - Archives, L. A. T. (2001, May 26). *Blind Climber, 64-Year-Old Reach the Everest Summit*. Los Angeles Times. <https://www.latimes.com/archives/la-xpm-2001-may-26-mn-2768-story.html> - **Archives is not the author's name as suggested, but the database name (Los Angeles Times Archives);**

- GUS. (n.d.-a). Ludność i gospodarstwa domowe. Stan i struktura społeczno-ekonomiczna. Część I. Ludność—NSP 2011. stat.gov.pl. Retrieved December 6, 2023, from <https://stat.gov.pl/spisy-powszechne/nsp-2011/nsp-2011-wyniki/ludnosc-i-gospodarstwa-domowe-stand-i-struktura-spoleczno-ekonomiczna-czesc-i-ludnosc-nsp-2011,11,1.html> - date missing, should be 2013;
- GUS. (n.d.-b). Stan zdrowia ludności Polski w 2014 r. stat.gov.pl. Retrieved December 6, 2023, from <https://stat.gov.pl/obszary-tematyczne/zdrowie/zdrowie/stand-zdrowia-ludnosci-polski-w-2014-r-6,6.html> - date missing, should be 2016;
- Page, T. (n.d.). *Blind photographer Pranav Lal captures images using sound* / CNN. Retrieved December 6, 2023, from <https://edition.cnn.com/2020/11/29/asia/pranav-lal-blind-photographer-spc-intl/index.html> - date missing, should be 2020;
- Strickland, E., & Harris, M. (n.d.). *Their Bionic Eyes Are Now Obsolete and Unsupported—IEEE Spectrum*. Retrieved December 6, 2023, from <https://spectrum.ieee.org/bionic-eye-obsolete> - date missing, should be 2022;
- *Vision impairment and blindness*. (n.d.). Retrieved December 6, 2023, from <https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment> - author's date missing, should be World Health Organization (WHO); date missing, should be 2023.
- ISO 9241-11: 2018 standard is not described in References;
- **Incorrect footnote**, e.g. p. 14 ("Their Bionic Eyes Are Now Obsolete and Unsupported," 2022) instead of (Strickland & Harris, 2022), p. 95 ("Let's Envision," n.d.; Be My Eyes, n.d; TapTapSee, n.d; Google Maps, n.d);
- **Typos**, e.g. Bubic instead Bubić (p. 17);
- **Figure 4** (p. 36) is unclear. As it present the process, other forms of visualization would be more appropriate;
- **Figure 14 (pp. 86-88) is not very valuable**. In my opinion, presenting these information in the table would be more useful and readable;
- **Too many information in tables**, i.e. in Table 1 Type of SSD (second column) is described as TVSSD or AVSSD while TV or AV would be more readable.

3.3 Accessibility of the doctoral thesis

It is a great pity that the Author, who emphasizes the need for accessibility in the dissertation (i.e. p. 99), ignores the principles of digital accessibility in the electronic version of the paper. For example, the illustrations presented are devoid of alternative descriptions and are therefore unreadable to people using screen readers, including the blind and visually

impaired. On the other hand, printed version meets most of the accessibility requirements, including suitable font type and font size.

4 Questions to Author

Below I have formulated the questions that arose for me after reading the dissertation:

1. The Author notes that the demographic structure of VIPs in Poland is specific. They are often older, less affluent and with education lower than the average education in Poland (pp. 11-12). How does this relate to the author's proposed solutions in the area of SSD? I am referring to issues omitted from the dissertation, such as the degree of acceptance of the technology and the design of interactions for older people?
2. The author presents several different studies, drawing general conclusions about SSD design. However, the participants in the studies were different, in particular the study described in Chapter 2 was done with non-disabled participants and in Chapter 3 with VIP. Disability may have significantly influenced the research findings presented. Non-disabled participants do not have developed sensory substitution techniques, so their performance compared to VIP participants was likely to be poorer. This may also affect the usability ratings of the systems studied. On the other hand, the participants in the study presented in Chapter 3 are exclusively blind. Their evaluations of the tested systems may be affected by the disability paradox (Bajcar et al., 2020; Trewin et al. 2015). Was this factor taken into account by the Author?
3. The participants in the research described in Chapter III are blind people who function on a daily basis with the support of technology, mainly a variety of mobile applications. This is not characteristic of the typical blind person. Such a deviation from the selection of participants in usability testing (cf. ISO 9241-304: 2008) should be described by the Author and justified. More broadly, can the Author address the problem of sample selection in research presented in the dissertation?
4. The Author does not analyse the learning curves of individual research participants in detail, and it seems to me that this would be a valuable addition to the analysis of the research results, especially in the context of the discipline of psychology. The analysis presented on p. 53 only applies to one of the studies described in the paper. I would suggest extending it to the other studies and presenting an analysis of performance according to training time (cf. Figure 7, p. 50)
5. Can the author elaborate on the idea presented in Chapter III (BrainPort and Colorophone system comparison): "The data suggests that users have different preferences and usage patterns when it comes to interacting with devices" (p. 75). It is interesting in the context of training assessment.
6. Could the Author explain research limitations for each presented study?
7. Even though the individual contribution of Author is stated at the beginning of every chapter, it is not clear for me enough. Therefore I would like Author to reflect on his

own contribution to each of the research presented in PhD thesis, to estimate it in percent and to show the biggest challenges met during the investigations.

5 Conclusions

Having reviewed Mr. Paweł Gwiaździński's dissertation, entitled 'Unseen Potential: Advancing Sensory Substitution Devices with a Human-Centered User Experience Approach (Niewidoczny potencjał: Rozwój urządzeń do substytucji sensorycznej z wykorzystaniem podejścia Human-Centered User Experience)', I believe **it meets the minimum requirements of the relevant legal acts**, particularly Article 187 of the Act of 20 July 2018, the Law on Higher Education and Science.

The dissertation addresses an important issue, and the problems identified by the author regarding the design and use of SSDs are significant. The author has demonstrated the ability to conduct scientific research and effectively communicate the implications of the research. The level of originality in addressing the scientific problem presented in the dissertation is satisfactory. However, it is noted that the dissertation lacks a comprehensive literature review, which could have provided a broader perspective on the subject matter and enhanced the interpretation of the research results.

6 References

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7 Glossary of abbreviations

CLRP: Colorophone

HCI: Human-Computer Interaction

SS: Sensory Substitution

SSD: Sensory Substitution Device

UX: User Experience

VR: Virtual Reality

VIRCO: Virtual Reality Cognitive Training System.

