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ACCEPTANCE AND USER EXPERIENCE OF WEARABLE ASSISTIVE DEVICES FOR INDUSTRIAL PURPOSES

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Abstract

This paper presents experience-oriented aspects of the development of wearable assistive devices (exoskeletons) for industrial purposes, an area which has only begun to be explored. Our research aims to examine user acceptance criteria for assistive devices and understand the meaning of interaction with wearable assistive devices for the users. The resulting models deliver new insights about the importance of user experience for technology acceptance and should be generally considered in development processes of wearable assistive devices.

Keywords: user experience, empirical studies, evaluation, technology acceptance, exoskeletons

1. Introduction

Occupational disorders of the musculoskeletal system are the most common cause of lost working days in Western countries (Storm, 2017) and are among the most important reasons for premature occupational disability (Liebers et al., 2013). Nevertheless, physically demanding work is indispensable in many sectors, as the automation of certain tasks is not possible for economic and technological reasons. Moreover, the development of the industry has led to a specialisation of workers, and thus to an increase in repetitive tasks and higher performance pressure (BAUA, 2015). The hand-arm-system is the most important interface for the use of work equipment and, in addition to the spine, it is most frequently affected by musculoskeletal disorders. This is particularly evident in automotive assembly, where the proportion of manual work is over 90%. This also includes ergonomically questionable activities, such as repetitive tasks or work in forced postures (e.g. overhead work), which are clearly related to musculoskeletal disorders (Lawaczeck, 2001). In this context, personal prevention measures such as wearable support devices; exoskeletons (BGHM, 2017) are gaining increasingly in importance. This sector is a rapidly growing and very diverse market. In the industrial field, however, assistive devices have only recently been introduced. In addition, the developments to date have mostly focused on the technical implementation, while the needs of the users have been a secondary consideration (DGUV, 2017).

Within the scope of a research project (2013–2017), the company Ottobock and the automobile manufacturer Volkswagen, together with other partners, have developed an orthotic bionic assistance system, the Paexo (Figure 1). This system is intended to reduce or prevent musculoskeletal diseases that can occur during overhead work. Paexo is a passive system that works without an additional energy supply. In order to provide relief for the shoulder region, the weight of the raised arms is transferred to the hips with the help of the assistance system.

Figure 1. Passive exoskeleton Ottobock Paexo

Ottobock has almost 100 years of experience in the development of medical products and knows its traditional users, the patients, very well. With the development of Paexo, the company is entering a new field, turning its attention not only to medical, but also to industrial context. This also changes the user group: the users are no longer diseased or injured patients, but a heterogeneous group of users with predominantly no health impairment or with varying degrees of illness.

With the help of medical products, patients can stabilize or improve their condition, so the user benefit is very obvious. The presence of an illness or injury thus generates a clear motivation to use and a high willingness to accept medical products. Employees in the industrial field often cannot recognize such an explicit motivation and additional value, since they have very different attitudes and opinions on prevention. Additionally, the implementation of body-worn assistive devices, as a new technological context, provides a particular challenge for user acceptance.

2. Experience of wearable assistive devices

Success and acceptance of products depend on objective and subjective aspects, these are the so-called instrumental (e.g.: effectiveness, ergonomics, reliability) and non-instrumental qualities (e.g.: aesthetics, identification, pleasure, meaning, cf. Thüring and Mahlke, 2007; Wölfel and Krzywinski, 2019a). The concept of user experience (UX) deals with non-instrumental qualities and their emotional experience. The relevance of the positive experience of the working environment is increasingly emphasised, as it affects well-being, motivation and performance (Burmester et al., 2015; Wölfel and Krzywinski 2019b).

In the use of wearable assistance systems, non-instrumental qualities gain even more importance, since the physical interaction with the product takes place directly on the body of the user, and thereby a new substantial level of the user experience appears.

In order to gain relevant insights for the development and the creative elaboration of next generation´s wearable assistive devices, a first version of Paexo was used in a user test to examine how acceptance for assistive technology devices arises, which interrelationships exist between user experience and acceptance, and which special aspects the body-worn product interaction entails.

3. Aspects of acceptance criteria and user experience

In response to the emerging tension between radical new technology and user acceptance, we analysed and adapted models known from acceptance research in view of user interaction and user experience using conventional methods from design and empirical social research, such as field observations, user surveys, user tests. It should be noted that only the terms of technology acceptance, the conducted user survey, and the analysis of the product language theory are presented here.

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Acceptance refers to a fundamentally positive attitude towards an acceptance object. Acceptance is personal, always subjective, arises from rational and emotional insights, and is based on voluntariness. (Schäfer and Keppler, 2013)
The peculiarity of technology acceptance in a professional context is, that the subject of acceptance (employee) perceives the acceptance object (assistive device) in an acceptance context defined by the organisation (voluntary or mandatory use context). Therefore, the acceptance attitude of the users also depends on the company structure and culture (Meissner and Trübswetter, 2018).
In order to understand the development process of acceptance, we studied the model of the innovation-decision process (Figure 2) according to Rogers (Arnold and Klee, 2016). Ideally, the process can be broken down into the stages *knowledge*, *persuasion*, *decision*, *implementation*, and *confirmation*. In the first phase, *knowledge*, the individual acquires knowledge about an innovation and how it works. This process is biased here due to socio-economic characteristics (education, school leaving certificate, etc.), personality traits (openness, conscientiousness, etc.) and communication behaviour (interpersonal communication, mass media, etc.). The second phase, *persuasion*, leads to a positive or negative attitude towards the innovation and results in an adoptive or negative decision. This attitude depends on criteria such as *relative advantage* (use benefit of the innovation compared to the previous technology), *compatibility* (compatibility with existing values, experiences and needs), *trialability* (possibility to try out an innovation), *observability* (degree to which the results of the innovation can be seen by others) and *complexity* (difficulty to understand the innovation and use it according to needs). (Arnold and Klee, 2016)

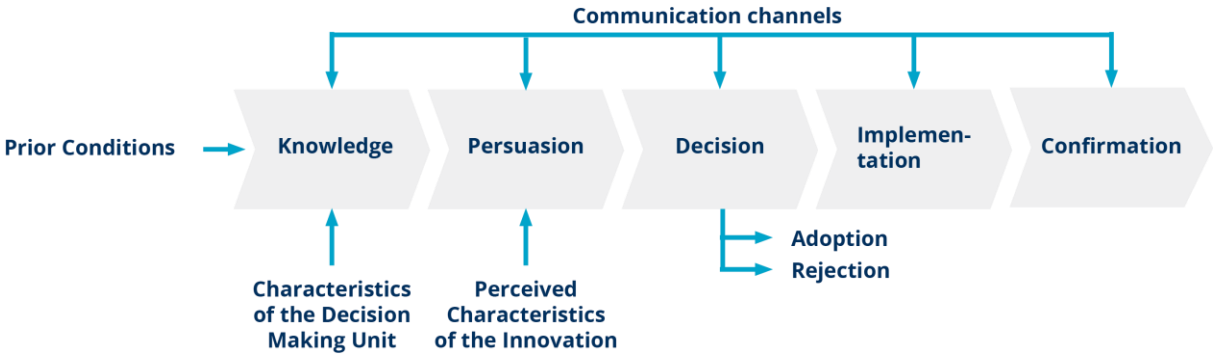

Figure 2. Innovation-decision process according to Rogers (Arnold and Klee, 2016)

These first two stages explain how the characteristics of the acceptance subject (user) influence the assessment of the characteristics of an acceptance object (assistive device), but acceptance research has so far dealt little with the level of interaction between subject and object, although this distinction can be a relevant factor in the development of acceptance. In human-robot interaction, the following levels can be defined: *coexistence* (acting in the same time and space), *cooperation* (pursuing the same goal) and *collaboration* (direct contact between the partners) (Meissner and Trübswetter, 2018). The interaction with wearable assistive technology device is a special form of *collaboration*, since the interaction takes place directly on the body of the user and has a direct effect on it. In order to characterize the special extent of the interaction level more precisely, we propose to use the term *union*. It can be presumed that when the intensity of interaction increases, so does the role of the user experience.
As these explanations show, acceptance depends on many factors. Preconditions such as the level of organization and the user characteristics cannot be influenced, but they must be considered in the development. On the other hand, the innovation characteristics can be completely defined in the development process. In order to achieve an adoptive decision by the user, the innovation characteristics have to be adjusted exactly to the needs of the users.

4. Study and findings

As part of a pre-pilot test in March 2018 at the Audi plant in Győr (Hungary) nine users (male, between 20 and 40 years old, of good physical condition) were wearing the Paexo for two weeks

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under conventional working conditions. In order to measure product experience, a guideline interview with pre-defined questions was conducted with the test persons. The goal was to collect qualitative self-disclosure information on users´ individual needs in relation to the assistance system in industrial use. Based on the interviews, it was possible to determine and describe more precisely five psychological needs of the users that were significant for the specific context (Hassenzahl et al., 2010 according to Sheldon et al., 2001).
The need for *security* is essential for the test subjects, but it is a prerequisite in a professional context. *Autonomy* and *competence* are also important, but are associated to the working environment and not to the assistance system. *Comfort* was classified as crucial as wearing comfort and also as factor of effectiveness in the work performance. *Physical thriving* was given a further meaning in this context: it was not only interpreted as the momentary experience of physical well-being, but due to the preventive character of the system, also as a confrontation with possible illnesses and one's own weaknesses. Many of the test persons admitted only reluctantly (or sometimes not at all) that they needed help in completing their work, thereby the need for *physical thriving* relates to the need for *self-esteem* as well.
The interviews revealed the relevance of the existing organisational structures and user attitudes, but also a clear potential for improving various aspects of the user experience of the assistive device.
It emerged that the use of an assistance system can have a significant impact on the user's self-image. This highlights the problem of technology acceptance from a new perspective and underlines the relevance of user experience in professional context. These insights could also be integrated into the model of Rogers' innovation-decision making process (Figure 3).

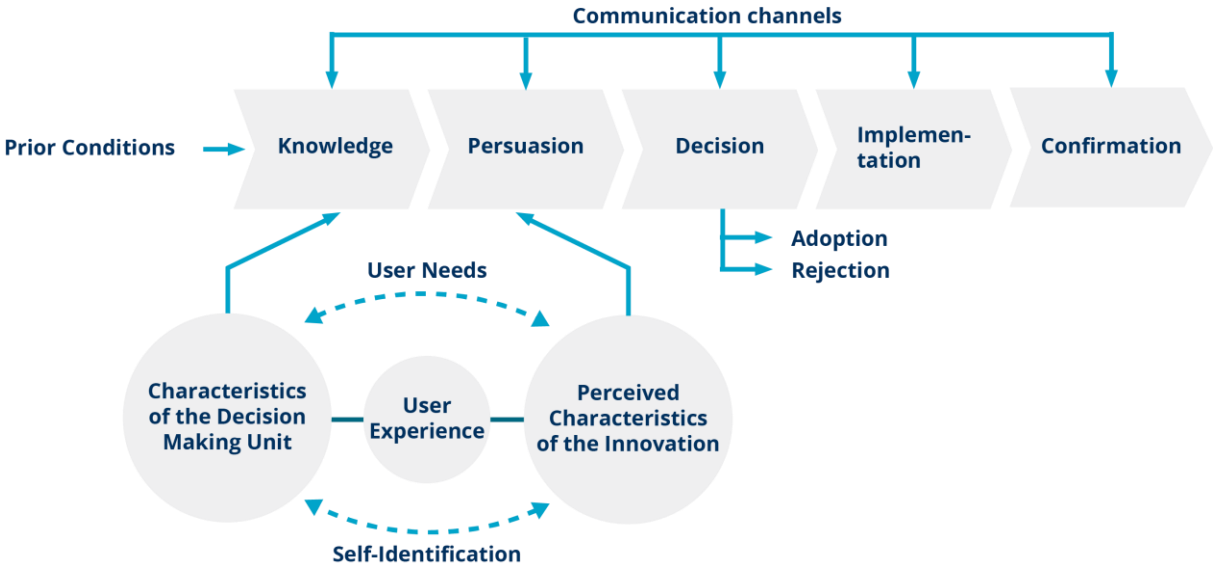

Figure 3. Innovation-decision process for wearable assistive devices (Arnold and Klee, 2016)

5. Product language as a tool for improving user experience and acceptance

The experience of an innovation is strongly influenced by how its characteristics are communicated. According to the “Offenbach approach”, communication between user and product is called product language. Signs of the product language play an elementary role in product usage, as they are responsible for:

- comprehensibility of the practical function and handling of the product
- identification, self-declaration, and usability of the product
- communication of product characteristics and product qualities (Steffen, 2014).

This shows that signs can be allocated to the concepts of relative advantage and complexity known from the model of the innovation decision-making process and that signs can be transformed into

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practical design approaches. For example, the Paexo assistance system should clearly show through its structure and design that it can be worn on the back / hip and that it supports the neck-shoulder-arm-area. Furthermore, its handling and operation must comply with the user's expectations and ideas (mental models). This requires a thorough analysis of the interfaces, whereby the design should rely on existing equivalents in order to facilitate the handling of the product.
Symbol functions of the product language are responsible for the emotional experience of the product. They communicate and support the identity of a person (lifestyle) and / or a company (brand) and determine the appearance and meaning of a product (Steffen, 2014). The preventive nature and the wearable character of an assistance system allow a special interpretation space for the symbol functions. The connotations of the symbols can be assigned directly to the user of the system. As the interviews have also shown, physical thriving and self-esteem play a very important role in the product experience and can be influenced positively or negatively by the symbolic functions (Figure 4). If the system is suggestive of an aid, the user may think it makes him appear weak or ill. This could lead to complete rejection of the product. The impressions and associations carried by the system must exclude a possible stigmatisation and enable a positive self-identification (e.g. the system should remind users of a sport device instead of an orthosis).

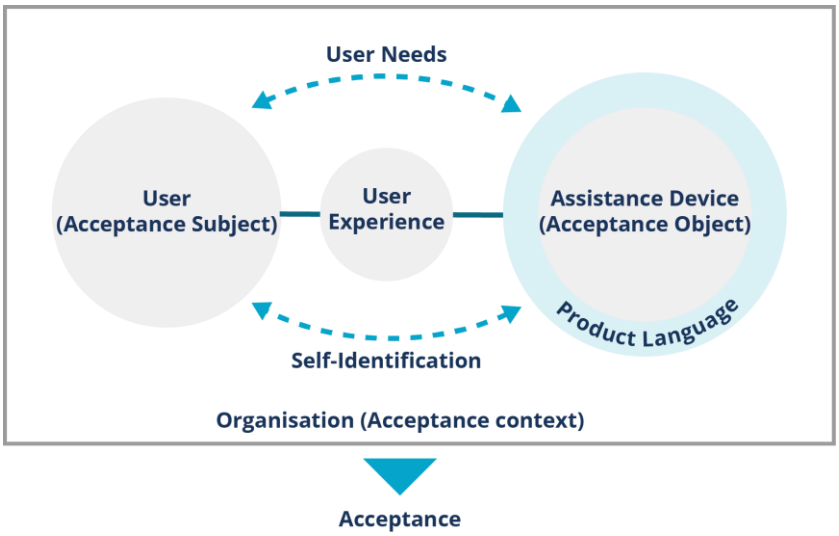

Figure 4. Acceptance model for wearable assistive devices, Meissner and Trübswetter (2018)

6. Summary and outlook

In the presented project, theoretical models from acceptance research and design theory were analysed and qualitative interviews were also conducted in order to characterise special aspects of user experience and the acceptance of wearable assistance systems. This allowed for improvements to user experience and acceptance through creative measures and changes.
The main conclusion that can be drawn is, that identification of assistive devices shows an associative character and the usage of an assistance system has a considerable impact on the user's self-image. These findings enlighten the question of technology acceptance from a new perspective and highlight the relevance of user experience in a professional context. However, the resulting additions to the model of the innovation-decision process should be examined in further investigations.
The interpretation of the results was undertaken in the further development of the prototypes, which were not presented here. The mentioned aspects could be converted into design principles and provided approaches for creative and constructive elaboration. A new product architecture for the assistance system was developed in an iterative prototyping evaluation process. Afterwards, the investigated aspects of the product experience and technical-functional modifications of the system could be synthesized in an improved product design.
Whether and to what extent acceptance and user experience could be improved should be evaluated on the basis of the modified prototypes in further comprehensive explorations. In the views of the

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authors, the resulting findings can be considered as a helpful and generally applicable contribution to the development process in a highly innovative technical environment.

References

Arnold, C. and Klee, C. (2016), Akzeptanz von Produktinnovationen, Springer Gabler, Wiesbaden. https://doi.org/10.1007/978-3-658-11537-1

BAUA, Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (2015), Arbeitsbedingungen in der deutschen Automobilindustrie (BIBB/BAuA-2012).

BGHM, Berufsgenossenschaft Holz und Metall (2017), Einsatz von Exoskeletten an (gewerblichen) Arbeit splätzen, BGHM No. 0059.

Burmester, M. et al. (2015), "Experience Design and Positive Design as an alternative to classical human factors approaches", In: Beckmann, C. and Gross, T. (Eds.), *INTERACT 2015 Adjunct*, University of Bamberg Press, Bamberg, pp. 153-160.

DGUV, Deutsche Gesetzliche Unfallversicherung (2017), Einsatz von Exoskeletten an gewerblichen Arbeitsplätzen.

Hassenzahl, M., Diefenbach, S. and Göritz, A. (2010), "Needs, affect, and interactive products–Facets of user experience", *Interacting with computers*, Vol. 22 No. 5, pp. 353-362. https://doi.org/10.1016/j.intcom.2010.04.002

Lawaczeck, M. (2001), Zur ergonomischen Beurteilung von Montagetätigkeiten in der Automobilindustrie, Ergon, Stuttgart.

Liebers, F., Brendler, C. and Latza, U. (2013), "Alters und berufsgruppenabhängige Unterschiede in der Arbeitsunfähigkeit durch häufige Muskel- Skelett Erkrankungen", *Bundesgesundheitsblatt – Gesundheits forschung – Gesundheitsschutz*, Vol. 56, pp. 367-380.

Meissner, A. and Trübswetter, A. (2018), "Mensch-Roboter-Kollaboration in der Produktion: kritische Würdigung etablierter Technikakzeptanzmodelle und neue Erkenntnisse in der Akzeptanzforschung", In: Weidner, R. and Karafilldis, A. (Eds.), *Technische Unterstützungssysteme, die die Menschen wirklich wollen, Konferenzband*, Hamburg, pp. 223-233.

Schäfer, M. and Keppler, D. (2013), Modelle der technikorientierten Akzeptanzforschung: Überblick und Reflexion am Beispiel eines Forschungsprojekts zur Implementierung innovativer technischer Energie effizienz-Maßnahmen, (Discussion paper No. 34), Berlin.

Sheldon, K.M. et al. (2001), "What is satisfying about satisfying events?", *Journal of personality and social psychology*, Vol. 80 No. 2, pp. 325-339. https://doi.org/10.1037//O022-3514.80.2.325

Steffen, D. (2014), Design als Produktsprache: Einführung, Vorlesung an der Hochschule Luzern.

Storm, A. (2017), Gesundheitsreport 2017, DAK-Gesundheit, Hamburg.

Thüring, M. and Mahlke, S. (2007), "Usability, aesthetics and emotions in human–technology interaction", *International Journal of Psychology*, Vol. 42 No. 4, pp. 253-264. https://doi.org/10.1080/00207590701396674

Wölfel, C. and Krzywnski, J. (2019a), "Human Needs as the Crux of the Matter in Product-Service Systems Development", In: Eriksson, Y. and Paetzold, K. (Eds.), *Human Behaviour in Design. Proceedings of the 2nd SIG conference*, Neubiberg. https://doi.org/10.18726/2019_2

Wölfel, C. and Krzywinski, J. (2019b), "Ansatz und Modell der User Experience cyber-physischer Systeme in professionellen Kontexten und dessen Kommunikation in Industriegüterunternehmen", In: *Arbeit interdisziplinär: analysieren -- bewerten -- gestalten. 65. Kongress der Gesellschaft für Arbeitswissenschaft*, GfA-Press, Dortmund.

https://doi.org/10.1017/dsd.2020.319 Published online by Cambridge University Press