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The dynamic adoption journey: a typology for users and non-users of occupational exoskeletons*

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***Abstract*— Various barriers prevent the adoption of occupational exoskeletons. It is therefore important to understand why some people are willing to use occupational exoskeletons, while others are not. To identify why people use or do not use exoskeletons, we created a typology describing different types of users and non-users. These types were created based on existing literature on internet adoption and social robots. Next, literature and empirical data were used to identify reasons why some people use exoskeletons and others do not use them (yet). The typology includes users with pain and users without work-related musculoskeletal disorders, but also non-users: resisters, rejecters, discontinuers, excluded or expelled non-users. It can be used by companies interested in implementing exoskeletons to identify possible early adopters. For exoskeleton designers, it can be used as a tool to identify non-users and focus on design strategies to enable non-users to become users (such as making exoskeletons that would fit people with a wide range of body shapes). Future research can use these types to identify users and non-users in field trials or pilot projects.**

I. Introduction

Recent reviews have concluded that although occupational exoskeletons can be effective by supporting people in the lab, so far these findings have not been found as effective as in the field [1]. Despite the availability of many different occupational exoskeletons to support workers with heavy or repetitive tasks (for an overview, we refer to the Exoskeleton Report[1]), their actual usage seems to be rather low [2]; we did not find evidence that these devices are used on a regular basis. However, different (pilot) projects and/or field studies have been organized to investigate the effect and acceptance of these devices at work [3], [4]. Results from these projects also include step by step approaches with practical advice [5].

Elprama et al. [6] have identified five sets of factors that enable or discourage the use of exoskeletons such as physiological factors, implementation related factors, work related factors, psycho-social factors, and policy related factors. Examples include the comfort of an exoskeleton, but also practical issues such as where exoskeletons are stored. fDespite having an overview of these factors, we currently do not have a clear idea who the early adopters or users of occupational exoskeletons are given a lack of data.

Therefore, our research contributes to existing research on occupational exoskeletons by identifying the different types of users and non-users of occupational exoskeletons. In addition, this research is relevant for rehabilitation robotics since users and non-users of rehabilitation robotics and occupational exoskeletons could have shared barriers for adoption such as cost and training.

We also describe how a person can evolve during the adoption process from a non-user into a user or the other way around. This is important, because there are different reasons why a person is willing to use or not use an occupational exoskeleton. Depending on these reasons, different strategies need to be applied (e.g., the company's exoskeleton use policy). Identifying types and creating a typology of this dynamic adoption journey will allow exoskeleton designers to prioritize overcoming barriers by focusing on improving specific parts of the design. This lead to the following research question:

What different types of users and non-users of occupational exoskeletons will exist in the near future?

To answer the research question, we build upon previous research on users and non-users of other technologies such as the internet from Wyatt [7] and social robots from de Graaf, Ben Allouch and Van Dijk [8] in combination with qualitative research data collected by ourselves and by analyzing scientific research papers. In rehabilitation research, we only found one study addressing the non-use of prostheses [9]. However, relevant predictor variables (such as using a

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[1]https://exoskeletonreport.com/product-category/exoskeleton-catalog/industrial/

TABLE I. THEORETICAL TYPOLOGY OF USERS AND NON-USERS OF OCCUPATIONAL EXOSKELETONS

	Profile	Description	Reference
User	User	People that use exoskeletons at work.	Own definition
Non-users	Excluded	People who do not have access to exoskeletons.	Wyatt et al. [7]
	Resister	People who have not used exoskeletons and do not want to use exoskeletons.	
	Expelled	People who stopped using exoskeletons involuntary.	
	Rejecter	People who stopped using exoskeletons voluntarily after they used it at least once.	
	Discontinuer	People who stopped using exoskeletons voluntary after using it for a while.	De Graaf et al. [8] and Rogers [10]

mobility aid at discharge) were not relevant in the case of exoskeleton use. Our methodology can also be used to create a similar typology for end-users of rehabilitation robotics. We based our typology of internet users and non-users of Wyatt [11] since she – to the best of our knowledge - was the first who coined the importance of studying non-users. First, we describe the types of non-users they have identified (section II.A), then we apply the types of non-users to occupational exoskeletons (section II.B) and create a description of a user of an occupational exoskeleton. Next, we used data from focus groups, an interview and existing literature to search for evidence of the different types of users and non-users we created (section V). Finally, we discuss the limitations of our study and the implications of our work for future research (section VI).

In this work we refer to occupational exoskeletons if we specifically want to address exoskeletons that can be used at work, while we use the word exoskeletons if we refer to exoskeletons in general (including applications outside industry such as rehabilitation).

II. RELATED WORK

A. *Types of non-users*

We are aware that occupational exoskeletons are still emerging technologies. Therefore, we start from a typology created for a well-established digital technology: the internet. Wyatt et al. [7] identified four types of non-users of the internet. The first type of non-user can be described as

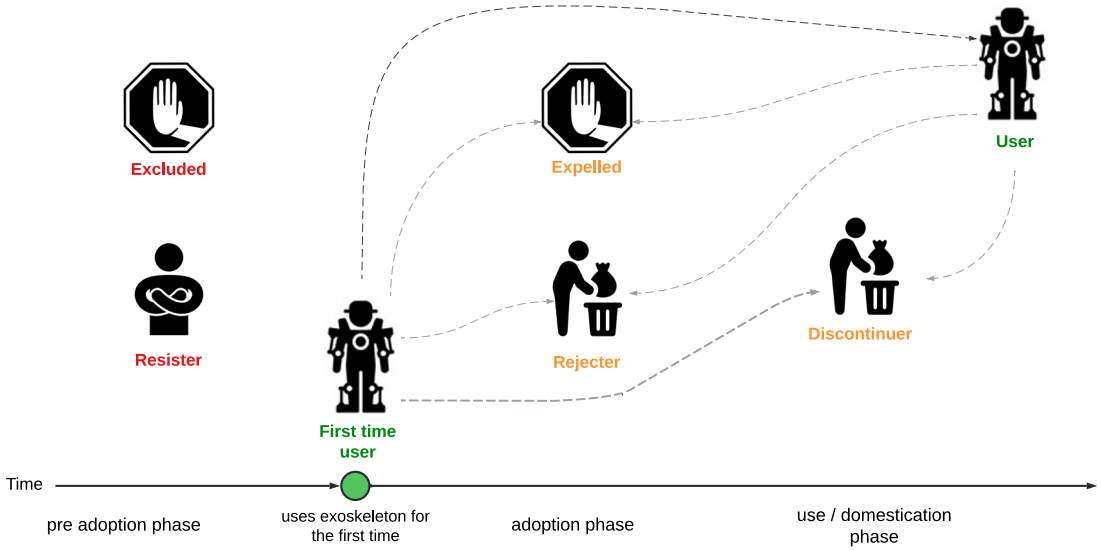

Figure 1. Chronological visualization of theoretical users and non-users of occupational exoskeletons. It illustrates that the excluded and resisters have not tried exoskeletons yet. Expelled, rejecters and discontinuers used exoskeletons at least once, but stopped using them. Users are the only type that keep using occupational exoskeletons.

resisters and consists of people that do not want to use the internet and therefore have never used it. The second group of people are called **rejecters** and they can be described as people who willingly stopped using the internet. The third group of people (**excluded**) can be described as people who never got access to the internet. The fourth and last group (**expelled**) consists of people who have lost their access to the internet involuntarily.

Based on [8], we also added the **discontinuers** as a fifth category, referring to people who stopped using a technology after initial use [10]. Their study [8] investigated the use of a social robot at people's homes. The main difference between rejecters and discontinuers is the point in time during which a technology was abandoned. They defined *rejecters* as participants who stopped using robots at two weeks or one month after it was brought to their home. *Discontinuers* were defined as people who stopped at two or six months.

B. Typology of exoskeleton users and non-users

Now we apply the definitions of non-users to occupational exoskeletons. We also added a description of a user. All profiles and descriptions can be found in Table 1. **Users** are people who use occupational exoskeletons. This category is rather broad. It could be a person who uses an exoskeleton on a daily basis, but it could also be a person who only uses an exoskeleton for a certain reoccurring task (but not necessarily every day). **Resisters** are people that do not want to use occupational exoskeletons and therefore have never used them. **Rejecters** and **discontinuers** are people who voluntarily stopped using occupational exoskeletons. The main difference is that rejecters stopped using exoskeletons after a short period of use, while discontinuers use them for a longer time. **Excluded** are people who never got access to occupational exoskeletons. **Expelled** are people who lost access to occupational exoskeletons.

These users and non-users can be divided into three different groups: people who have never used an exoskeleton (resisters and excluded), people who do not use exoskeletons anymore (expelled, rejecters and discontinuers) and finally users (people who still use exoskeletons). We have positioned these profiles on a fictional timeline to illustrate the chronological order in Figure 1. Although there is initially a temporal aspect to the types of (non-)users, a person can change into a different type of user or non-user over time. For instance, an excluded person could change jobs and gain access to occupational exoskeletons at their new place of work and become a user or a rejecter after a short time of use. A resister could theoretically change their mind one day and start using an exoskeleton and become a user. Since we have now listed different types of users and non-users, the next step is to find data to support the existence of these types and their motivation to use or not use an occupational exoskeleton.

III. METHODOLOGY

We were involved in three pilot studies in three companies. The study consisted of several data collecting methods including a survey [11], field testing [12] and five focus groups.

During the pilot, each company had two exoskeletons available. The dredging company and the air conditioning factory had one Laevo V2 (the Netherlands) and the BackX from SuitX. Additionally, the dredging company also had the ShoulderX from SuitX (USA). Finally, the windscreen company tested one Laevo and one a BackX from SuitX (USA). At the end of the pilot, we organized five focus groups to learn about the experiences of the employees with occupational exoskeletons. Each focus group participant had worn one or two exoskeletons for a total maximum of four hours.

In addition, we were able to identify and interview a person (not included in the pilot) who is a long-term user of an exoskeleton in the workplace. We matched the insights from our data with the examples reported in the published empirical industrial or organizational exoskeleton studies (for a detailed description of these scientific papers included we refer to [6]).

IV. PARTICIPANTS

Twenty-nine males and one female (n = 30) participated in one of the five focus groups (3 – 8 people per focus group). These focus group participants worked in a dredging company, the distribution center of a vehicle windscreen repair and replacement company and one company producing air conditioning systems. One exoskeleton user (1 female) was interviewed. The ages of all participants have a mean of 36.0 years and a S.D. of 9.1 years.

V. DATA ANALYSIS

The five focus groups and the interview were transcribed. Their transcripts and the scientific papers were analyzed using MaxQDA (software to support the analysis of qualitative data). We used the theoretical typology listed in Table 1, to carefully search for examples of these types. Once found, we labelled them manually with the type of user or non-user. Given the current adoption trajectory of exoskeletons, firsthand data on long term users is hard to find. For non-users, we focused on data describing people that stopped using an occupational exoskeleton and the reasons that were named in research studies. Also, because we did not find any data on people who were still using exoskeletons, we aimed at identifying the main motivations why people would use occupational exoskeletons. The process of defining the non-users and users was mainly the result of frequent discussions (e.g., reflecting on the data and the existing types from previous literature) among the first (researcher with a background in human-technology interaction) and the last

author (a sociologist). This method is called constant comparative method [13] and it is a well-known method used in qualitative research.

VI. Results

We will first discuss the evidence found in our qualitative data in combination with related literature how the different types of users manifest in practice when talking about the use case of occupational exoskeletons. Next, we will discuss the different types of users (users experiencing pain and users without WRMD (work-related musculoskeletal disorders) and non-users (discontinuers, resisters, rejecters, expelled, excluded). An overview of all types can be found in Table 2.

A. Users experiencing pain during work

One of the participants in our focus groups has a neck hernia and he reported to be willing to use exoskeletons. Similarly, using focus groups, recent research [14] had found evidence that suggests that people with lower back pain are more willing to use exoskeletons. Therefore, we hypothesize that one type of users are people who already experience pain at work. The pain experienced is probably the main reason that they are willing to wear occupational exoskeletons.

B. Users without WRMD

We interviewed one user who regularly uses an exoskeleton (approximately 6 hours per day). She explained in her interview that her main motivation to wear an exoskeleton is to prevent injuries and work until retirement without problems. What also helped her was participating in a test in which the tension in her muscles was measured and she could clearly see that working with an exoskeleton yielded lower muscle activity. She usually wears her exoskeleton if she has to do heavy lifting tasks or a lot of repetitive work. However, in summer – because of the increasing temperature – she wears her exoskeleton for a shorter period.

C. Rejecters and discontinuers

In literature, we found several reasons why people stopped using exoskeletons during field studies: discomfort [3], [4], [15], inability to complete tasks [3] and fit issues related to the height (too short) of the participant [4]. Although de Graaf et al. [8] differentiate between rejecters (actively rejecting and stop using exoskeletons before adoption) and discontinuers (stop using after adoption), we did not find enough evidence in our data to define a clear cutoff point between the two types. This is mainly due to the lack of long-term research to date. In our focus groups, we found several participants who match the description of a rejecter. They did try using an exoskeleton but did not want to use it yet on a daily basis. The main reason for this was that they did not think that the exoskeletons they evaluated were good enough to support the wide range of tasks they have to complete in their daily work. Some participants expressed the willingness to reevaluate the use of exoskeletons once the design improved. This suggests that with a new exoskeleton, a rejecter or discontinuer could evolve into a user.

D. Resister

The next three types hypothetically exist, but due to their nature they are more implicitly present in the literature and in our data. A *resister* is a person who has never used an exoskeleton because they do not want to. These people are less likely to be found reported in research papers in which

TABLE II. Typology of users and non-users found in our study.

	Profile	Description	Examples
User	Users experiencing pain during work	People with existing pain seem to be more likely willing to use exoskeletons.	[14] and in our focus groups
	Users without WRMD	People who would like to prevent future injuries and report not to care too much on how an exoskeleton looks.	Interview with user
Non-users	Excluded	People who are excluded from using exoskeletons (in field studies) due to their height or sex.	[3] and our own experiences with pilot
	Resister	People who refuse to use exoskeletons.	-
	Expelled	People who got the opportunity to use exoskeletons but who lost access to exoskeletons.	Interview with user and own experiences with pilot
	Rejecter	People who stop using exoskeletons after a (short) while. Rejecters stop very quickly after using an exoskeleton. A discontinuer uses an exoskeleton for a while and then stops using an exoskeleton. Reasons for abandoning exoskeletons includes discomfort, the inability to complete tasks and fit issues.	[3], [4], [15] and our own experiences with pilot
	Discontinuer		

exoskeletons are tested simply because they simply refuse to participate in the research. Nonetheless, resisters could also still potentially exist in companies given that pilot projects in companies also start by asking employees to volunteer.

E. Expelled

Expelled non-users are people who stopped using exoskeletons even though they would still like to use them. We did not find papers describing these types of people and we did not encounter them in our work. The regular user that we interviewed explained to us that she had a colleague who also used to use exoskeletons at work, but that he was no longer working in her place of work. In theory, he could be an example of an expelled non-user. We hypothesize that all people that have participated in (lab or field) experiments, pilot projects or in our focus groups could potentially belong to this group. They probably had access to an exoskeleton during the research or pilot project. However, if exoskeletons were not available after those projects and exoskeletons were not implemented at work, they also had to stop using the exoskeleton even though they might have been willing to keep using it if one was available.

F. Excluded

Excluded non-users are a group of non-users that do not have access to an exoskeleton and therefore they have not used one. The most plausible reason for not having used one is because they simply do not have exoskeletons at work. Since exoskeletons have not been implemented at a large scale, we expect that most people fall in this category. We found evidence for two other reasons of exclusion (of participating in field trials): being female [3] or because of one's height (too tall or too short) [16], [17]. In Hensel and Keil [3] it was decided to exclude females from the research for reasons of expected discomfort in the chest region and a low number of females in their population [3]. In our own experience with pilot projects with occupational exoskeletons, we learned also that female workers were less likely to participate in experiments with exoskeletons for reasons of expected discomfort in the chest area with the Laevo V2.

Once excluded non-users gain access to exoskeletons, they could evolve into one of the other users or non-users depending on their characteristics. Given that occupational exoskeletons are not (yet) used at a large scale, we assume that most people currently fall in this category. Hypothetical reasons why non-users are excluded from access could include the price of an exoskeleton or because management is hesitant to bring this new technology into their company. It could also be that their exoskeletons broke, and it was not replaced, or management simply removed existing exoskeletons to be used.

VII. Discussion

We have created a typology for occupational exoskeletons based on literature and empirical data. This typology can be used by researchers as a way to categorize existing (non-) users. Companies designing exoskeletons can use this typology to strategically improve the design of exoskeletons. For example, understanding why rejecters or discontinuers stop using an exoskeleton can encourage the development and design of future exoskeletons. Improved designs could lower or remove existing barriers (such as fit issues or comfort) towards adoption and attempt to change non-users into users. Companies interested in implementing occupational exoskeletons can use the typology to identify potential early adopters of these devices.

Our typology is built on the assumption that a person's type can change due to reasons identified in this paper. Each person starts as a non-user, but due to external circumstances or the design of the exoskeleton, a person can change into a different type of non-user or become a user of occupational exoskeletons. As such, we view this process as a dynamic journey.

In our analysis, we mainly focused on identifying reasons why people stopped using exoskeletons in field trials. However, there are more reasons for using or not-using exoskeletons as can be seen in the framework of Elprama et al. [6] that also includes hypothetical enablers and barriers for adoption. Similarly, given that we only identified two types of users, but actual users are challenging to find, it is possible that in the future more different types of exoskeletons users will be identified such as users who only rarely use exoskeletons.

There is a lack of long-term research reported [6] and we think that given the current maturity of exoskeletons, this will happen in the near future. Our typology is ready to be used to study the adoption of abandonment of occupational exoskeletons (for example in field and/or pilot studies).

For now, it is still important to keep in mind the potential distinction between rejecters and discontinuers for occupational exoskeletons. Especially in the initial phase of adoption, it is possible that next to the design of an exoskeleton, the lack of good training and insufficient support at work could be the main reason for people to reject occupational exoskeletons early in the adoption phase. However, despite good training and support at work, other factors could be the reason for discontinuing the use of exoskeletons.

A limitation of this typology is that it is still a work in progress and that the number of hours a non-user wore an exoskeleton was limited to 4 hours maximum. We think it is likely that more data about users and non-users will be available in the future. This allows validation of existing types both but also opportunity to modify or merge existing types or to identify new types.

Future research could investigate whether the types described in this paper will uphold over time, when more people are gaining access to occupational exoskeletons. Furthermore, it would also be relevant to investigate if rejecters and discontinuers stop using exoskeletons for different reasons and whether it would still be relevant to distinguish these two different types in the future. Although this typology is now focused on (non-)users of occupational exoskeletons, in future research our methodology could also be applied to exoskeletons used for rehabilitation purposes to identify different types of users and non-users.

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