Co-exploring Interaction Opportunities for Enabling Technologies for People with Rheumatic Disorder

Suhas Govind Joshi(✉) and Jørgen Valen

Department of Informatics, University of Oslo, Oslo, Norway
{joshi,jorgeval}@ifi.uio.no

Abstract. This paper presents a case of co-design for people with rheumatic disorder to support the argument of opening up the design space to include interaction opportunities found in the physical world. The position argued for is that opening up the design space beyond common screen-based interfaces may contribute to the design of enabling technologies for people with rheumatic disorders by acknowledging their varying capabilities during both design and use. The presented results consist of one thematic analysis of home interviews and group discussions as well as one statistical analysis of the results from a formative evaluation of six conceptual prototypes developed along with the participants. The paper uses the combination of the thematic analysis, the six conceptual prototypes, and formative evaluation of performance scores and preference ratings to demonstrate how our co-design process involving users with rheumatic disorder in all phases allowed participants to discover both limitations and opportunities as they explored and co-designed alternative concepts.

Keywords: Enabling technology · Rheumatic disorder · Tangible interaction

1 Introduction

The wide range of conditions falling under the umbrella term rheumatic disorder, as well as the fluctuating nature and individually perceived manifestation of the associated physical impairments, complicates the design of enabling technologies intended to support a highly heterogeneous composition of users. Selecting specific interfaces usually involves certain assumptions about the users' capabilities for interaction. By using, for instance, a touch-based interface, we have already assumed by design that the users possess the necessary physical preconditions to perform the interaction mechanisms and finger-based gestures such as swiping and pinching.

In this paper, we argue that involving the users in all phases of the design process, and simultaneously developing a better understanding of their capabilities for interaction when selecting interface, can increase the chances for both successful and prolonged interaction for users with rheumatic disorders. We support our position by presenting a thematic analysis highlighting some of the challenges associated with rheumatic disorders and rely on data from an evaluation of six co-designed conceptual prototypes involving 15 people from the target demographic as well as 11 expert users. We explore whether opening up the design space to include interaction opportunities

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found in the physical world (as opposed to just screen-based designs) may contribute to the design of enabling technologies for people with rheumatic disorders by acknowledging their varying capabilities.

The research presented in this paper expands on the previous work carried out by the authors on designing enabling technologies (e.g., [1, 2]). While many of the participants were older adults, this paper revolves around a particular set of physical impairments and does not limit the target demographic and participants to only older adults.

2 Related Work

The hundreds of conditions associated with the umbrella term rheumatic disorder can manifest themselves very differently, and the fluctuating nature of the various conditions yield highly individual and temporal experiences [3]. These fluid and often-unpredictable characteristics complicate the design of enabling technologies that are based solely on specific conditions or umbrella terms such as rheumatic disorder because the success of enabling technologies ultimately lies in the intertwining between the personal perspective of the user and the contextual circumstances [4]. The various manifestations of rheumatic disorders that may influence our physical opportunities and limitations have been outlined in the past, for instance in [5] where the characteristics of rheumatoid arthritis are described or in [6] where the effects of various conditions, e.g., Parkinson's disease are explained. Examples of how these physical symptoms of rheumatic challenges affect the opportunities to interact with technology as well as challenge the assumptions designers can make about the users' physical capabilities have been specifically discussed in the context of aging (e.g., [1, 7–11]). However, the manifestation of physical impairments such as those associated with rheumatic disorders may be equally troublesome for people who are not considered as older adults as studies are pointing towards a range of disabilities found in cases where young or middle-aged people live with physical impairments [9]. It has also been argued that enabling technologies should acknowledge that the experience of technology is a concern that involves the intertwinement of a multitude of co-existing factors, among which we find physical impairment. The authors of [8] argued that you cannot detach the intended users or users groups when raising questions about what technologies are. It is further argued that the multitude of interacting factors complicate the predictability of use and the related outcomes [4]. Thus, we draw on many different bodies of work on the relationship between physical impairment and the users' readiness towards technology, but common for all is an underlying understanding of the users' capabilities as something defined by more than just a medical diagnosis.

3 Research Methodology and Methods

The overarching methodology follows the Participatory Design (PD) approach we have previously applied in an extensive research project spanning over four years [1, 2]. The strategy emphasizes a respectful and inclusive design process and is heavily influenced by the phenomenological ideas of Maurice Merleau-Ponty [12] and his notion of the lived body. This strategy offers a framework for understanding able-bodied human-technology relationships through a phenomenological lens that focuses on how the technology meets the capable body and attempts to understand the interaction through the user's bodily experience of a phenomenon. The exact nature of how physical impairments affect the ability to engage with technology is highly subjective and something we consider as continuously evolving through life. Our approach emphasizes that participants should be able to engage in co-design activities on their own terms.

Our research was structured into two main components: data gathering and evaluation. The data gathering consisted of demonstrative interviews from the target demographic and two group discussion sessions with a local branch of the Norwegian rheumatism association with 49 users. The collected data material included audio recordings of group discussions, field notes from observations, photographs, and transcripts from interviews. This data was used in a thematic analysis where we attempted to structure essential challenges. Based on the data gathering sessions, six conceptual prototypes were co-designed with the users to serve as thinking tools. These prototypes (depicted in Fig. 1) were designed to learn more about the capabilities of the users and help us reflect about the assumptions about the users and should therefore not be considered as end-results. The prototypes were used to carry out a task-based formative evaluation of performance and preference when interacting with alternative tangible text input interfaces. The evaluation sessions were carried out at the homes or care facilities of the participants. 15 people struggling with various forms of rheumatic challenges constituted the user group (average age of 71.4 years), while 11 health practitioners or HCI experts formed the expert group. The procedure for both the thematic analysis and the evaluation are further described in the next section.

Fig. 1. The six co-designed conceptual prototypes used during the evaluation

4 Results and Analysis

The result section is divided into two main components. We present the results from a thematic inductive analysis, and we outline the primary results from a statistical analysis of the performance scores and preference ratings from a task-based evaluation of the six conceptual prototypes.

4.1 Thematic Analysis

The data used in the analysis was gathered through group discussion sessions and home interviews. We followed the approach for inductive thematic analysis outlined in [13]. The home interviews revealed interesting perspectives, for instance, one participant showing us around her home explaining adjustments made to technology at multiple points of interest in her apartment (as seen in, e.g., [14]). She had introduced several modifications to support her own capabilities for interaction, for instance using a pencil with a rubber band as an extended pen for her computer keyboard (leftmost image in Fig. 2).

Fig. 2. Examples of how homemade adjustments can support interaction with everyday objects

The thematic analysis revealed two main clusters, namely *everyday activities* and *interaction challenges*. The former cluster included all contextual and health-related concerns, particularly those found in the home setting, e.g., button on clothes and use of utensils. The latter cluster consisted of all issues related to interaction with technology. Table 1 presents a summary of this latter cluster discovered in the thematic analysis with emphasis on key challenges and involved enabling aids when interacting with technology. While we focus on only one of the two clusters in this paper, findings from both clusters contributed to the informed co-design of the six conceptual prototypes.

Table 1. Overview of challenges related to interaction with technology

Interaction challenge	Particular difficulties	Enabling accessories/aids
Reachability	Stiffness and joint pain when writing with regular computer keyboards	Homemade stylus, speech to text software
Long-term strain injuries	Fatigue from using a regular computer mouse	Ergonomic computer mouse, rolling or trackball mouse
Exhaustion	Resting arms when using mouse and keyboard	Ergonomic keyboard, speech-to-text software
Readability issues	Eye strain and fatigue when reading small text	Text-to-speech software, magnifying software
Eye-straining	Bright light from screens	Screens with adjustable light

4.2 Evaluation of Conceptual Prototypes and Statistical Analysis

The participants were given a similar text input task as commonly used on modern screen-based systems across the six devices in randomized order. To further avoid any learning effects, the task and the concepts were introduced and explained ahead of the evaluation to normalize the level of familiarity and expectancy among all participants. For each task, completion time was recorded, and all participants were also asked to rate preference, simplicity, and easiness of use during the post-evaluation interview. The rating used a relative scale, i.e., grading from least to most preferred (coded as 1–6). As such, the data consisted of both quantitative and qualitative results. Figure 3 shows two of the users as well as one group of experts participating in the evaluation.

Fig. 3. Two participants from the user group and one group of experts during the evaluation

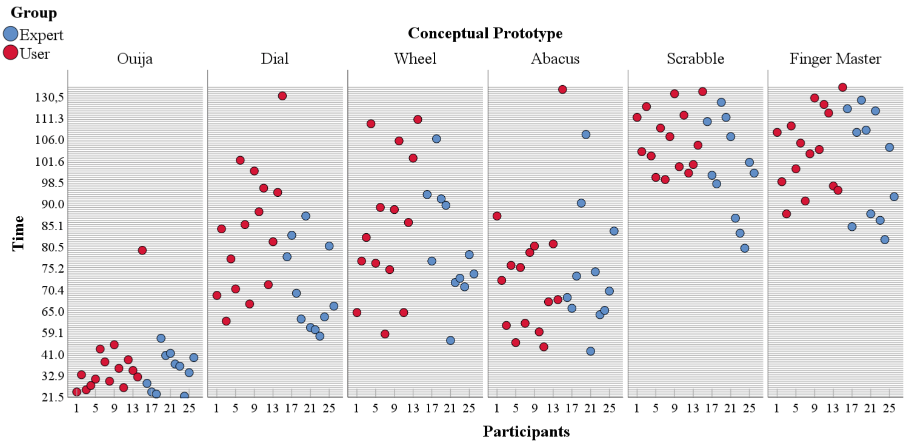

Fig. 4. Performance time for all participants sorted by conceptual prototype

The scatterplot in Fig. 4 shows the performance time for each participant across all six conceptual prototypes. An exploratory data analysis using factorial ANOVA *(group x prototype)* studied the variance in performance time across these prototypes for each group. The results indicated a statistically significant main effect for the groups, $F(1, 143) = 6.70$, $p < .005$. There was also a statistically significant main effect for the prototypes, $F(1, 143) = 60.471$, $p < .001$. The main effects for the different prototypes

(η_{ρ}^{2} = .679) was then subject to a post hoc analysis where we applied Bonferroni correction. The core results were that the Ouija prototype differed significantly from all other prototypes (p < .001 for all comparisons) and that the Scrabble and Finger Master prototypes also differed from the rest, but in the opposite direction. When comparing the variance for each prototype separately and simultaneously isolating the user group, only the Ouija prototype demonstrated a statistically significant difference from the rest at the <.05 level.

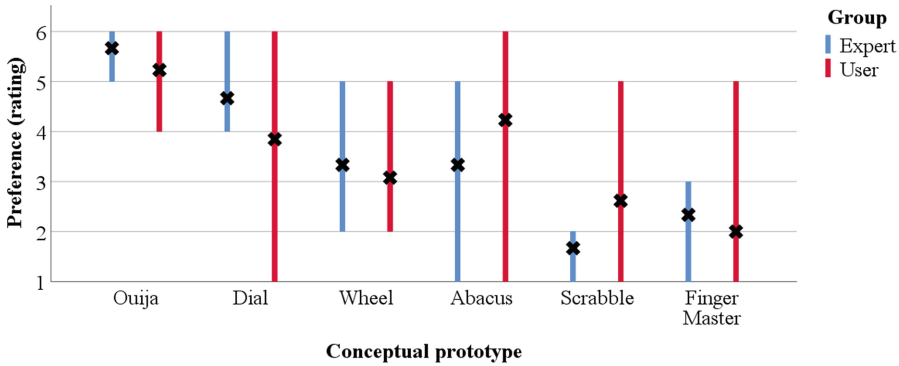

Fig. 5. Preference rating for each of the six prototypes coded by group

The second set of results presents the preference rating given on average to each of the six conceptual prototypes. These results helped us study how the mean and range of preference rating varied between users and experts for each of the prototypes. Figure 5 outlines the range bars and mean ratings for each of the six prototypes. The bars represent the minimum and maximum rating given for each prototype by experts and users, and the crosses signify the mean rating across all participants in a group. Another factorial ANOVA *(group x prototype)* was used to study the variance. The results revealed a statistically significant main effect for prototypes, $F(5, 390) = 94.19$, $p < .001$, $\eta_{\rho}^{2} = .414$, as well as a similar result for *prototypes x group*, $F(5, 390) = 2.25$, $p < .05$. From the figure, we can see that the range was similar for only the Wheel prototype, and that a larger scale was used in the user group in all the five cases where there was a range difference between the users and experts. The extreme example would be the Scrabble prototype where the experts limited their preferences to two values only while the user group's ratings ranged across five values. Finally, we can also see that the expert group only rated the Abacus prototype ($M_{experts} = 3.38$, $SD_{experts} = 1.58$; $M_{users} = 4.24$, $SD_{users} = 1.43$) and the Scrabble prototype ($M_{experts} = 1.69$, $SD_{experts} = 1.07$; $M_{users} = 2.66$, $SD_{users} = 1.27$) lower on average than the user group.

5 Discussion

As seen in Fig. 5, the user group relied on a broader range when rating the prototype with only one exception. Our key findings emerged as we paired the statistical analysis with the qualitative data from the post-evaluation interview as well as the thematic analysis summarized in Table 1. We relied on the combination of both quantitative and qualitative results as the combination of these two diverse sets of data provided different focus of measurement and psychometric characteristic when studying a human-technology relationship in the context of enabling technologies [1, 4]. Involving contextual factors during the preference rating was particularly common within the user group (as also discussed in [4]). Accessing past subjective experiences [3] through interaction with only conceptual prototypes allowed the user group to shed light on factors not considered by the experts, e.g., long-term factors such as straining on muscles, which was reflected in their fluctuating performance rating (Fig. 4). For many of the participants, working on a computer was a necessity, but simultaneously an activity that turned exhausting and straining over time. One participant said she depended on her computer for most of her work, but she could never take on regular full-time employment relying on frequent computer use due to devastating fatigue and pain over time. One theme brought up during the home interviews and group discussions was that several challenges were related to fatigue and pain caused by poor working position, forceful keying, duration of use, and workstation setup – some of which are also mentioned in [15]. Two of our conceptual prototypes (Dial and Abacus) were subject to critique from certain participants due to the afforded working positions and quickly resulting in pain. When describing her experience with the Dial, one participant said: *"...the working position becomes completely skewed, so I get terrible pain in my shoulder region"*. However, this experience simultaneously made the participants aware of how other alternatives among the six conceptual prototypes offered new opportunities. For instance, the Finger Master prototype – despite being one of the most time-consuming and least preferred options overall – allowed participants to discover new configurations of the human-technology relation. One participant using the Finger Master noted that having the keyboard in her lap minimized straining in the shoulders and offered a more relaxed working position. Another participant praised its resemblance as it reminded her of older cell phone keypads and the mechanisms associated with text messaging.

On the other hand, there were also cases of consensus. One such case was the Ouija prototype that scored best on both performance time (Fig. 4) and preference rating (Fig. 5). Having all letters (i.e., input options) visible at all times similar to a regular keyboard was essential to most of the participants in both groups. Another reason for its high performance and preference was that it allowed the whole hand rather than just individual fingers to be used. Thus, we argue that the broader range among the users in Fig. 5 demonstrate how different people with rheumatic disorder can find both limitation and opportunities when the interaction is more configurable also regarding how it acknowledges and responds to bodily capabilities of the users.

6 Conclusion

Our overarching salutary perspective attempts to provide a positive outlook by focusing on the participants' capabilities [1], and this paper has attempted to demonstrate how users with rheumatic disorder found both limitations and opportunities when opening the space and giving them a chance to have a more proactive role in the design process. We have reported from one thematic analysis of home interviews and group discussion as well as one statistical analysis of performance and rating scores from a formative evaluation of six conceptual prototypes developed along with the participants. We have demonstrated how participants used past experiences to discover opportunities to counteract interaction challenges in current interfaces. Using even conceptual prototypes as thinking tools helped both the participants and us to easier access the subjective experiences of rheumatic disorders and supported the co-discovering of new spaces for design in the physical world tailored specifically for this user group.

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