THE ROLE OF PROTOTYPING IN ERGONOMIC PRACTICE AND RESEARCH TO ANTICIPATE NEW PRODUCTS AND SERVICES

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Abstract. This article argues for the dual role of prototyping in facilitating abductive thinking in research and practice within "Ergonomics" and "Design". Moreover, this duality also pertains to the development of innovative commodities, as well as in the acquisition of new knowledge.
Since PE investigates real-life scenarios the aim of the researcher is to understand the nature and complexity of the future state of the system. In this sense prototypes can be used as probes into that future state due to the fact that once implemented they unveil real interactions and transformations of the system. Based on the act of design as a critical inquiry in itself, prototypes and prototyping are then being more and more perceived as carriers of reflection and argumentation
From a pedagogical perspective, prototyping exposes students to larger issues around creating and testing operational models of knowledge. Reversely, when being engaged in collaborative project with industry, prototyping can play an expanded as well as a more effective role in conceptualizing innovative solutions in an efficient manner.

Keywords: Prototyping, Prospective Ergonomics, Research and Practice.

1 Introduction

Traditionally, ergonomics has been focusing on correction and prevention. As such, the role of the ergonomist in product design has been to provide and interpret data about people, their behavior and cognition through task analyses, performance data and design guidelines [1]. These endeavors primarily aimed at ensuring that products are safe, usable, easy to learn and effective – largely functional, performance-related issues.

Moreover, it has been identified that the potential of ergonomics is underexploited [2], because organizations and their stakeholders mainly focus on performance and outcome. Even though there is some recognition among design and engineering practitioners and researchers about the potential benefits in applying ergonomics in design, it is not sufficient [3]. The lack of ergonomics being applied in design is also explained by Hollnagel and Woods [4]. Traditional ergonomics never questioned the validity of human-machine distinction, and therefore encountered problems in developing a systems view comprising of stakeholder interactions in context. As such, Norros [5], perceived a pressing need for conceptual innovation. This means that within a frame of systems

thinking, ergonomics needs to be design-driven, while maintaining its focus on two closely related outcomes: "performance" and "well-being" [2, p.1].

"Design Ergonomics", rely on numerous data collection methods from a wide variety of disciplines to investigate how human behavior and needs may determine the development and improvement of products and services. Many of these collection methods are either analytical or predictive, but still lacks the interactive attributes to integrate research with practice to anticipate future needs and trends. As such, there is a need for Ergonomics to capitalize on the exploratory and synthesis characteristics of the design profession, for example "prototyping".

This article aims to propose a conceptual framework for prototyping in PE by connecting the research nature of ergonomics with the practice-oriented nature of when anticipating innovative products and services. Alternatively, it promotes the value of prototyping as a tool for acquiring new knowledge at the cross-roads of research, practice and innovation. The following sections discusses how prototyping in the broadest sense can become a valuable asset for ergonomic (design) practice in the anticipation of future needs and development innovative products and services.

2 The Practice of Ergonomics

Little attention has been paid to how ergonomists work and the factors that influence their practice [6]. The methods, which they are using, are seldom connected to the processes they are meant to support. Moreover, a significantly important aspect of ergonomic practice, which has often been ignored is, the concern with the safe and efficient use of products [7].

However, most of the writing on ergonomic practice, appear to aim at promulgating a particular approach to ergonomics which researchers believe will be effective – not understanding what actually works for ergonomists in their professional practices. Moreover, when trying to find evidence of ergonomics' effectiveness, literature reviews indicate that there is a predominance of intervention projects run by researchers, not practitioners [8, 9].

The role of the ergonomist as a "skilled helper" who helps clients to identify problems and develop strategies to accomplish goals has been discussed by Shorrock an Murphy [10]. These authors also claimed that in successful consulting, ergonomists empathize with the parties they work with, to understand their concerns as well as the broader contexts in which these concerns unfold [11].

The importance of understanding the context in which ergonomic practice occurs is also emphasized by Kirwan [12] and Wilson [13]. However, more research is required into the actual roles and (micro-)practices of the ergonomist while engaged in daily work [10].

As such "Practice Theory" will be elaborated in this section to emphasize the *tacit, informal* and *actual doings*, which is reflected in the sociology of everyday life [14]. First to make the distinction between practice and praxis, practice guides activity, while praxis is the activity itself. Hereby, 'practices' refer to shared routines of behavior in the broadest sense, including traditions, norms and procedures for thinking, acting and using 'things' [15, p.619]. Praxis refers to what people actually do. Practitioners are the

actors, who make, shape, investigate and execute. They include not only senior (strategic) design executives, but also designers, researchers, makers, prototypers, etc. Based on the concept of "Praxis", which encompasses "Practice", their work is complex and diffuse. It embraces the routine and the non- routine, the formal and the informal, activities at the corporate center and activities at the organizational periphery [16]. These activities include meetings, conducting interviews, presenting concepts, entertaining potential and existing customers, talking with suppliers and distributors on the phone, organizing and conducting usability studies, ad-hoc "firefighting", and many more.

3 Prototyping in Ergonomics

Physical prototypes have been applied comprehensively in product development processes over the centuries in producing innovative representations and forms to connect better with the expectations of different stakeholders [17]. As an instantiation of a future outcome [18], they can be defined as "*physical manifestations of ideas or concepts*" [17, p.9] or as "*representations of a design made before final artifacts exist*" [19, p.424]. Moreover, from an ergonomic perspective, collaboration with users demonstrated the positive impact of prototyping in innovation. As such, prototyping facilitated the creation of shared mental models among participants, clears misunderstandings, promotes creativity through ambiguity, creates emotions through haptic experience, and fosters coordination [17].

To make useful design contributions, ergonomics practitioners need to bridge the gap between analysis and synthesis by translating human factors information into well-conceived, user-centered design ideas [20]. This requires them to use or at least be familiar with 2-D, and 3-D visualization tools to explore alternative problems and solutions. which are highly complex [21].

Prototyping and prototypes in HCI and interaction design play multiple roles ranging from open-ended explorations to provoking critical reflections and testing or validating hypotheses [22]. Houde and Hill [23] were among the first to emphasize the importance of the questions the prototype asks and hence what the prototype *prototypes* through its different dimensions (e.g., role, look, and feel, and implementation). Reference to this HCI context, Buchenau and Fulton Suri [19] motivated and unpacked *experience prototyping*, which aimed to bring multiple stakeholders together to "*gain first-hand appreciation of existing or future conditions through active engagement with prototypes*" [19, p.424]. Experience prototyping provided an approach that leveraged the use of prototypes to explore and experience aspects of potential technological futures. Hereby, low fidelity prototypes are the most suitable to demonstrate "proof of concept" [24] in the early stages of collaborative design. In these stages, collaborative prototypes facilitate contextualization, action, and reflection. They were found more suitable for communicating multiple design needs and exploring creative design variations with various stakeholders than higher fidelity prototypes. Through co-creation and design activities, involving different stakeholders, they open up the design space for insightful interactions and emphatic design solutions [17].

Finally, prototypes are also often assumed to be a point on a trajectory toward a fully realized commercial product used to test specified needs or unmet requirements.

In either case, new knowledge and insights are produced through the use of research prototypes [25].

4 Prospective Ergonomics: Anticipating Future Products and Services

Traditionally, too few ergonomists work in companies and have little control over budgets and people. They are mainly seen as protectors of workers, rather than creators of products, systems and services [26].

Presently, the value of ergonomics extends beyond occupational health and safety and related legislation. The field of ergonomics has become more proactive with respect to problem solving, design, functional usability and the planning of innovative products and services [27]. They have extended the meaning of "preventive" to "prospective", by emphasizing the "forward-looking in time" aspect (as opposed to retrospection) through the "intelligence analysis" of individual, social, cultural, political, economic, scientific, technological, and environmental factors [28, 29]. The extension to PE also calls upon ergonomists to facilitate design or be design-driven by encouraging different stakeholders to become more involved in innovation and creation processes.

Hereby, the concept of "prospection" is being developed around speculative scenario building in a balanced and simultaneous manner, as a challenge for ergonomists to consider multiple objectives, such as well-being, exposure to learning, and profit maximization. From this systemic perspective, ergonomists need to manage practical implications and ethical trade-offs [30], considering short-, and long-term interdependency between performance and well-being. This means that innovation through a PE lens aims for pluralistic outcomes and is systemically embedded in context. It also implies that PE supports the implementation of processes and methods by "realistically creating and innovating the external world" in an anticipative and speculative mode, by considering that human activities are bounded by rationality.

From this prospective ergonomic perspective, scenarios are intended to assist decision-making at three main stages in the design process [31]: (a) the analysis of problem situations in the start of the process, (b) the generation of design solutions at various levels of complexity, and (c) the evaluation of these design decisions according to User-centered Design (UCD) criteria. In this context, it can be argued that the purpose of scenarios in the early stages of design is not only to provide an accurate vision of future user activity, but also to crystallize designers' current knowledge and assumptions about future activity. Thus, from this point of view, scenarios of future use in PE are not just a material for analysis, but also a product of creative design [32].

5 Discussion

Results indicate that prototyping is a useful tool to facilitate abductive thinking in research and practice within "Ergonomics" and "Design". However, prototyping for the two purposes is not the same, and so to make this activity serve as a bridge, it will be necessary to adjust slightly both their processes and outcomes [33].

Firstly, it should be clarified that prototyping has become increasingly important in other forms of design that are not only physical. They include communication, interaction, service, experience, and so on. Furthermore, they have been used in a broad range of disciplines, and not traditionally thought of as design, such as chemistry, biology, computer science, math, drama, education, and so on. Secondly, a prototype is often a learning and information gathering tool for the practitioner to help him or her to reduce uncertainty and narrow the conceptual space until a commodity is produced. Thirdly, for the researcher, prototyping is also a learning tool, aimed at knowledge acquisition, rather than the commodity at the end. It challenges ergonomists to focus on designing experiences to enlarge the design space, as well as to develop the design discourse 'beyond the object'.

Figure1 shows how prototyping advances the research process. Every research prototype developed and implemented expands the conceptual space and the view of the future state of the system, so that each iteration results in a larger understanding of the context and problem space.

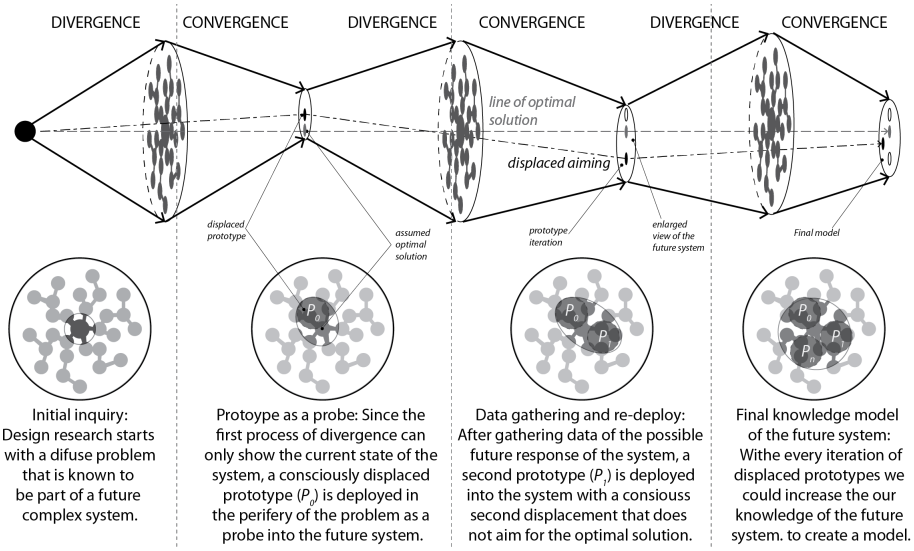

Fig. 1. The prototyping process within a divergence and convergence model for design research [33].

In Figure 2, the combined diagram shows how this might work, with the conceptual space expanding toward a larger understanding while the decision space narrows towards the final commodity. The context of the project, however, introduces additional complexities. The learning necessary to make decisions toward the next step of the commodity is not typically the same as the learning necessary to develop a larger understanding in the sense of reusable knowledge. For example, a designer interested in practically improving the experience of airplane travel might want to create prototypes to learn more about appropriate leg room, sitting comfort, seat accessibility, etc. There will be some useful existing literature from ergonomists to draw on. A design researcher, on the other hand, might want to create an operational model for designers of

what factors go into the mental model of "being a passenger," which could apply to air travel, but could equally well be useful for any kind of travel from tandem bicycles to hang-gliders to trains and buses. The prototypes, rather than focusing on the airplane seating, will explore aspects of what it is to be a passenger, of which airplane seating might be one

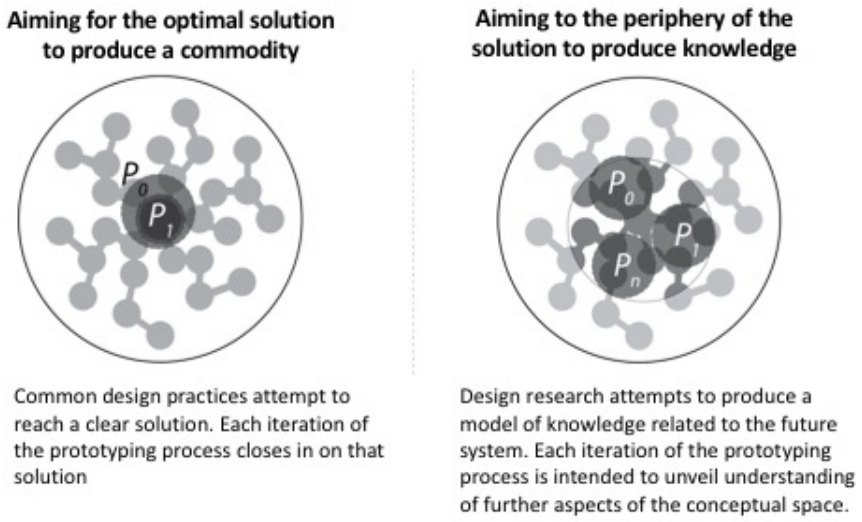

Fig. 2. A prototyping process with both practice and research outcomes [33].

Since PE investigates on the possible scenarios of reality, the goal of the researcher is to understand the nature and complexity of the future state of the system. In this sense prototypes can be used as probes into that future state due to the fact that once implemented they unveil real interactions and transformations of the system. Based on the act of design as a critical inquiry in itself, prototypes and prototyping are then being more and more perceived as carriers of reflection and argumentation. For instance, Galey and Ruecker [34] articulated how knowledge is embedded within a prototype and how this can advance knowledge production about the world. This perspective on the purpose of prototypes is being supported by Lim, Stolterman and Tenenberg [18], who presented an in-depth investigation into the fundamental nature of prototypes. They articulate two key dimensions of prototypes in support of this argument. Firstly, prototypes as filters, which allows designers to purposefully leave out aspects of the design at a particular phase of the design process, while exploring radical variations of other qualities. Secondly, prototypes as formed manifestations of design ideas, which enables project stakeholders to experience the idea, and designers themselves to reflectively engage in a conversation with the design idea [35]. Complementary, Boer and Donovan [36] accentuated the notion of provotypes, which are provocative prototypes that "embody tensions surrounding an area of interest, in order to support collaborative analysis of that area and to collaboratively explore design possibilities" [36, p.389]. Central to the notion of provotypes is the analytical and generative role they play in bringing a project's multiple stakeholders together around critical issues bound to the design goal.

6 Conclusion

In practice, designers and ergonomists are usually not able to follow the lead of an idea that is not in the direct trajectory of creating a commodity. This article argued for the need that prototypes should adopt the dual role to facilitate the development of innovative commodities, as well as to acquire new knowledge pertaining design and prospective ergonomics.

As a response to the limited understanding of prototypes, its usage and users in the design process, this article concludes that:

- At an operational level, prototyping should be understood as a platform where research and design meet. This platform is characterized by certain qualities of representation, which is not the final commodity, but a form of intervention for experiential learning and collaborative exploration. (Bogers and Horst, 2013; Kolb & Kolb, 2017).
- A structured way of introducing prototyping complements the overarching system of interacting and collaborating entities, which is necessary to facilitate research and practice to develop new knowledge, as well as anticipate future products and services.
- When enlarging the design space, prototype resolution need not to be aligned with the progression of design activities.
- Within the context of an industry-sponsored classroom project, the pedagogical intent of prototyping lies in exposing students to larger issues around creating and testing operational models of knowledge. Reversely, industry may also be interested in how prototyping can play an expanded as well as a more effective role in conceptualizing innovative solutions in an efficient manner.

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