Where do We See Cognitive Ergonomics in the Near Future?

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Abstract. This position statement relates cognitive ergonomics to the fields of human factors/ergonomics and human-computer interaction. The role of cognitive ergonomics in design interventions, now and in the near future, is considered.

Keywords: Cognitive ergonomics · human factors/ergonomics · human-computer interaction.

1 Introduction

The workshop topics include the question of whether cognitive ergonomics (CE) is a separate discipline and how to relate it to other fields. Diaper and Sanger [5] mention three aspects that form a discipline.

- Agreement to a general problem,
- A common set of practices, and
- A body of shared knowledge.

Similarly, Cohen and Lloyd [3] define scientific disciplines as having their own distinct sets of key knowledge, methods, and assumptions that separate them from other disciplines. The authors point out that disciplines change due to changes in the environment and interactions with other disciplines. They borrow the vocabulary from biological evolution to describe the evolution of scientific disciplines in terms of selection, mutation, speciation, extinction, parallel evolution, and heterosis[1]. This paper relates cognitive ergonomics to the fields human factors/ergonomics (HFE) and human-computer interaction (HCI). The objective is to inform or prepare a discussion at the workshop about where do we see CE in the (near) future.

[1] Cohen and Lloyd also note that "the idea of scientific disciplines is both old and new". It can be traced back to the ancient Greeks, but the use of disciplines "as the primary unit of internal differentiation of science is an invention of nineteenth century society" [3].

2   CE as sub-discipline of HFE

CE emerged as a sub-discipline of HFE[2] to better respond to the introduction of information and communication technology and increasing cognitive demands on workers in the 1970s. Dul et al. [6] describe key characteristics of HFE which may also apply to CE, but here with a focus on people's mental processes and on cognitive artefacts[3].

– HFE takes a system approach: Systems consist of humans and their environments (formed by artefacts ranging from simple tools to whole organizations [8]). They are considered at different levels (micro-/meso-/macro-level).
– HFE is design driven: HFE can be involved in all stages of systems design. The aim is to shape the environment around the capacities and aspirations of humans (first try to fit the environment to the human, only then select or train them to fit the environment).
– HFE focuses on two joint design outcomes: performance of the system (e.g., productivity, efficiency, effectiveness, quality, reliability, sustainability) and well-being of the human (e.g., health and safety, satisfaction, pleasure, learning, personal development). The objective is to find an optimal compromise between well-being and performance.

It is, according to Dul et al. [6], the design orientation that differentiates HFE from disciplines such as sociology and anthropology. And in contrast to disciplines such as psychology, medicine, and engineering, HFE looks at both the human and the technology side. HFE deals with work systems but the understanding of work systems has been expanded and now includes, for example, domestic and leisure environments and the consideration of consumer products and services [5, 6]. In their strategy paper for HFE, Dul et al. [6] point out that the potential of HFE to contribute to the design of future systems is under-exploited. The authors see the strength of HFE in the application of participatory design approaches which can actively involve employees and product/service users in design processes. But "HFE must demonstrate its value more successfully to the main stakeholders of system design" (for example, decision makers such as managers and system experts from technical and social sciences).

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[2] HFE is defined by the International Ergonomics Association (IEA) as "the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimise human well-being and overall system performance" (adopted version, 2000).

[3] According to the IEA, CE is "concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system. The relevant topics include mental workload, decision-making, skilled performance, human-computer interaction, human reliability, work stress and training as these may relate to human-system design."
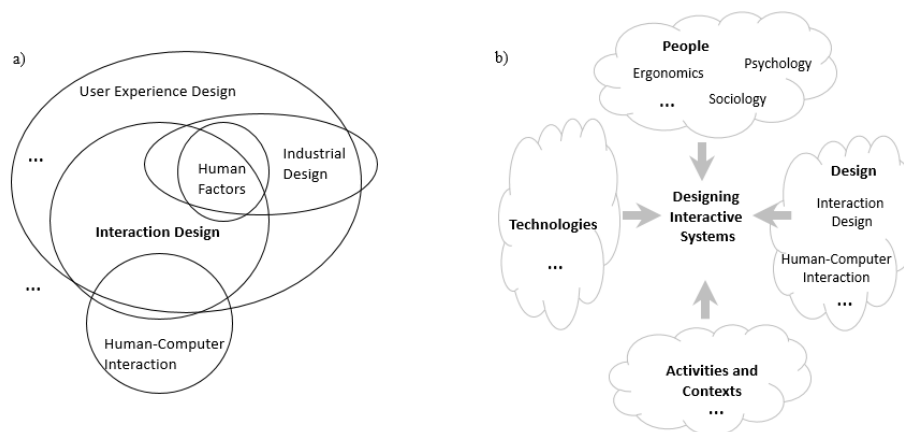
Fig. 1. Positioning of HFE and HCI as contributing disciplines to interactive systems design: a) by Saffer, b) by Benyon et al. (see [11] and [1] for the complete diagrams).

3   CE and HCI

Let us now look more closely at the relationship between CE and HCI. Some may consider HCI to be a sub-field of CE, some may not see a big difference between the two fields. CHI, the largest HCI conference, calls itself "Conference on Human Factors in Computing Systems". Diaper [4] defines HCI "as an interdisciplinary engineering discipline that is a subdiscipline of ergonomics". The definition of the HCI as a field given by the ACM SIGCHI[4] suggests a different view which is also supported by Papantoniou[5]: "CE's difference from HCI is mainly the broader focus of the analysis to include the worksystem as a whole, as opposed to the user-computer interaction, as well as other factors (organizational, historical etc.) that traditional HCI often avoids to address, and hides under the "context" label instead". Figure 1 refers to illustrations from 'schoolbooks' depicting interactive systems design as multidisciplinary approach. What is interesting here, in the context of this paper, is the positioning of HFE and HCI (CE is not explicitly mentioned). Figure 1a) shows HFE and HCI as 'non-overlapping' disciplines, Figure 1b) puts HFE in the 'People cloud' and HCI in the 'Design cloud'.

Norman [10] considers the practice of HCI as still mainly an art form and compares it with HFE practice (not with CE in particular): "The discipline that calls itself "Human Factors" in the United States and "Ergonomics" elsewhere in the world is a real, true engineering discipline, with established methods and pro-

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[4] HCI is "concerned with the design, evaluation, and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them" (ACM SIGCHI, 1992).

[5] https://www.interaction-design.org/literature/book/the-glossary-of-human-computer-interaction/cognitive-ergonomics. For Papantoniou, CE is synonymous with cognitive engineering.
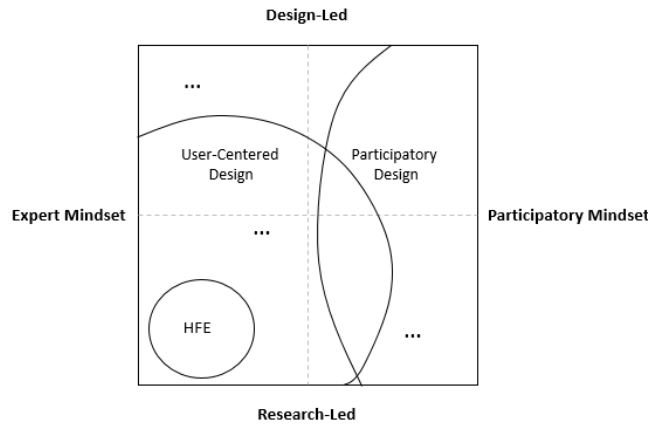
Fig. 2. HFE positioned in a map of design practice and design research by Sanders (see [12] for the complete diagram).

cedures[6]. It is what HCI ought to be" [10]. Falzon, an (constructive) ergonomist, states that "[a]ctual ergonomics practice is more an art than a science. It requires a constant adaptation to the peculiarities of the situation to be tackled, based on the expertise of a particular HFE specialist" [8].

4   The Evolution of CE

The evolution of a discipline is influenced by the developments in 'the external world'. Dul et al. [6] mention, for example, continuing automation of work systems and rapid, continuing developments in ICT affecting individuals' consumption behaviors. It is also influenced by the diverse, partly conflicting perspectives on the discipline and by the interaction with other disciplines. A distinction between an 'insider's view' and an 'outsider's view' may be useful for a better understanding of the current role of a discipline. For example, HFE experts emphasize the design driven nature of HFE (see above) and make the criticism that HFE is often incorporated within engineering disciplines and psychology (and not seen as its own discipline) [6]. HCI experts instead consider HFE/CE as not being a design discipline [10] but as "a source of knowledge for [HCI/interaction] designers to use as guidelines for ensuring good usability"[7]. HFE experts point out that "HFE commonly takes participatory design approaches" [6] (especially in organizational ergonomics), a view that is not necessarily shared by people outside the field (see, e.g., Figure 2). Another source for the development of a (sub-)discipline are the internal discussions and conflicts. For example, the constructive approach to HFE advocated by Falzon and colleagues [7, 8] sets

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[6] Norman refers, for example, to the profound knowledge and systematic methods in analyzing situation awareness, tasks, collaborative activities (co-located or not).

[7] https://www.interaction-design.org/literature/topics/cognitive-ergonomics

the development of individuals, collectives, and organizations as the target of ergonomic design interventions, and thus puts more emphasis on reflective practice and on HFE methods supporting reflective activities of employees than other approaches.

Where do we see CE in the near future? If we follow the ideas of Cohen and Lloyd [3] that were mentioned in the introduction, we understand the evolution of (sub-)disciplines as a process in which

- Key characteristics of disciplines are formed (selection and mutation),
- New (sub-)disciplines emerge (speciation),
- Myopic views of complex phenomena can be held (inbreeding),
- Disciplines disappear because of waning interest, little new useful research, or certain power relations (extinction),
- Two or more existing disciplines create independent solutions to new environmental demands (parallel evolution),
- Disciplines are 'merged' or combined (heterosis).

In this context, we can perhaps understand the current state of CE and HCI as parallel but overlapping developments; both fields came into being as responses to technological developments in the 1970s, both emphasized that technology must fit human needs, but CE emerged as a sub-discipline from HFE and HCI emerged to 'counterbalance' software engineering practices[8]. Both fields have to continuously question their objectives, methods, and practices. Carroll [2] describes effects of the multidisciplinary but also fragmented field of HCI on researchers and practitioners as follows. On the one hand, an isolation "from some portion of the field's foundations" is often to be found as a coping strategy among HCI specialists. On the other hand, they accept the need for amalgamating different user-centred design methods and techniques [2]. Harper et al's [9] statement (in 2008) about the near future of HCI (in 2020) may support a converging view on CE and HCI: "...we need to have a new conception of the 'computer' in HCI. We need a better way of understanding how the embedding of digital technologies in everyday artefacts, in the built structures around us and in the natural landscape is transforming our surrounding environment into a physical-digital ecosystem. We now need to address not just the design of the artefacts themselves but also the spaces within which these artefacts reside. More than this, design has to deal with deeper, systemic issues".

Do we see CE as an own (sub-)discipline in the future, or do we see a new discipline (with what name?) combining CE with other disciplines, or do we see CE disappearing? In [3], three strategies to survive as discipline are mentioned which help to think about justifications for CE and possible new directions.

- Turning inward and strengthening boundaries,
- Forming strategy alliances with stronger disciplines,

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[8] Authors such as Diaper [4] even suggest to abolishing the historical division between software engineering and HCI "because both are engineering disciplines concerned with the same types of systems and their difference is merely one of emphasis, with software engineering focusing more on software and HCI more on people".

– Reconstituting the discipline in a newer and larger field of study.

I think the strength of CE, and of HFE in general, is the design orientation and the focus on well-being and performance as joint design outcomes. Ergonomic design interventions are exploratory, they are "hypotheses about how artifacts shape cognition and collaboration" [13] and require active participation of all stakeholders. It is neither expected in the near future that 'pure' engineering disciplines fully take up this design perspective nor that disciplines such as psychology or social sciences become design disciplines. I can imagine, in the long run, that we (need to) have a deeper, common understanding of the co-evolution of artefacts, people, and practices, and this may perhaps lead to less specialization.

An alliance of CE with some areas of HCI[9] seems to be plausible for several reasons. Both fields extended their scope: considered activities now also include activities in domestic, leisure or public environments. Existing conceptions of performance and corresponding methods cannot be applied without revision and CE could benefit, for example, from HCI research on user experience. As mentioned above, HCI needs to reconsider the conception of 'computer' as computers are now embedded in all sorts of (everyday) artefacts and the field could benefit from the more systemic and ecological CE approaches. Current HCI design follows user-centred and participatory design approaches but mostly with a product-oriented perspective. CE can complement these practices with more exploratory design interventions [13] and more emphasis on reflective activities of stakeholders (e.g., [7]). It was also indicated above that HFE/CE practices still have to be more effectively integrated in existing design and production processes (e.g., by increasing the awareness of decision makers) and this certainly applies to HCI design practices as well. Both fields need to revise their understanding of users' needs ('HCI jargon') or well-being ('CE jargon') and of other basic assumptions. For example, current systems often are based on an overuse of resources. Do I feel well as an individual knowing that I destroy natural resources for future generations (including own children)? What other factors than the commonly considered ones (such as mental workload or work stress) have an impact on (mental) well-being? Do we need to change our understanding of systems?

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[9] I do not refer here to more technology-oriented HCI research (e.g., invention of new interaction technologies).

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