Anke Dittmar, University of Rostock
Dianne M. Murray, Independent Consultant
Gerrit C. van der Veer, Vrije Universiteit Amsterdam
Harry J. Witchel, Brighton and Sussex Medical School

Cognitive Ergonomics—A European Take on HCI

Insights

- Cognitive ergonomics (CE) traditionally includes well-being, applied psychology, and a wider contextual and ethical interest than HCI.
- The CE tradition focuses more on theory, discussion, and processes as compared with HCI.
- Researchers in CE and HCI should allow their respective processes and outcomes to cross-pollinate, as they are complementary in their scientific contributions and cultures.

At a 1982 European meeting focused on cognitive engineering, all participants were psychologists, trying to make control rooms and computer programming languages easier to use from a cognitive perspective. This was the starting point of what is now known as *cognitive ergonomics* (CE). CE is an academic field that developed mainly in a European context. It has always been concerned with designing for human use by studying the interaction of complex tools, cognition, collaboration, and context. Its goals are the optimization of, or the compromise between, human well-being and the performance of a work system. This natural tension, when trying to integrate well-being and performance, makes CE much more discussion based than other similar disciplines. The European Association of Cognitive Ergonomics (EACE) was originally created in 1982 to foster CE as a viable research community. Since then, the association has annually sponsored and organized in many European countries, together with local researchers, the European Conference on Cognitive Ergonomics (ECCE) [1].

Like any other field, CE undergoes constant evolution due to changes in the environment and interactions with other fields. Specifically, the focus of CE has widened in the past decade, so our understanding of the field needs to be

updated to take CE out of particular work settings, such as cockpits and control rooms, and into day-to-day culture and the wider environment. As such, there is an increasing awareness that the CE discipline is becoming more conflated with human-computer interaction (HCI), despite differences in genesis and development. In this context, to rethink CE, we convened a workshop at ECCE 2019, held in Belfast, U.K. [2], which prompted this article. An overriding goal was to bring together researchers and practitioners with an interest and expertise to consider whether CE is actually a separate discipline in its own right and how it relates to the other disciplines dealing with humans and their interactions with systems, machines, and applications.

Multiple research communities, with their particular cultures, as well as the interactions between them are needed to address challenges in the design and use of technological artifacts. Here, we first present a short historical background by contrasting European developments in CE with those of HCI in North America. We then discuss changing understandings in CE in terms of new domains and concepts. We conclude with a reflection on the nature of scientific disciplines and communities in an attempt to determine how CE and HCI as disciplines can evolve and thrive alongside one another.

THE ROOTS AND HISTORY OF COGNITIVE ERGONOMICS

The future of a scholarly field is connected to its past and to the social context of its development [3].

With the advances and spreading of information technology in the 1970s, an understanding of the need for usable systems increased, in academia as well as in industry. In North America, industry seems to have taken the lead. For example, at the first CHI conference in 1982, more than half of the Steering Committee and Program Committee had industrial affiliations. Their approach toward the design of usable systems often began by analyzing a successful commercial design (see, e.g., [4]). In Europe, on the other hand, a large proportion of usability-focused work started in university contexts. There has been a strong regional flavor in many parts of Europe in the research, design, and development of usable systems, as well as with respect to the type of application domain considered.

While it would be impossible to generalize about research activity in an entire country, in broad brush strokes, there were differences in emphasis on users, their machines, and their cognitive processes while using them. In France, the emphasis was on thinking and planning, such as psychological analysis of programming projects; the collaboration in complex process-control situations, such as aviation; and on task analysis. In Scandinavia, researchers focused on the value of people, including ergonomics and safety issues of interactive systems. Trade unions and university researchers developed a general design approach (participatory design), encouraging strong user involvement during the design process. In the U.K., design focused on understanding cognitive aspects of human behavior, user-centered design, and mental models. Dutch developments resulted in contributions in how to think about how to think, such as the psychology of programming languages. The German-speaking part of Europe moved from the ergonomics of programming languages to the design process and the foundations of building user interface management systems (UIMS). Different strands developed in Spain, in Italy, and in other European countries. Although CE attempts to integrate human, machine, and context, at that time the researchers in the fields that now make up CE were not integrated.

The emergence of CE can be read as a European attempt to integrate these diverse approaches. An early milestone was the first ECCE in 1982 that led to the foundation of EACE [1]. The association developed into a forum of researchers with a broad spectrum of specialisms. Its aims were, and still are, to provide a forum to collect and present current findings in the field, to bring together researchers (both junior and senior), and to foster intensive and wide-ranging discussion. Submission topics and conference themes expanded from early, specific concerns in human factors and ergonomics (such as process control) and sociotechnical systems (such as tasks and organizations) to wider investigations in computer-supported collaborative work (such as collaborative activities) and in virtual reality/virtual environments (such as virtual and physical interactive systems). The ECCE conferences are designed to cater to a broad congregation of researchers across Europe by using English as the common language. Accepted contributions are reviewed primarily as relevant and timely triggers for inspiration and scientific discussion.

NEW DOMAINS AND CONCEPTS

CE is traditionally defined by the International Ergonomics Association (IEA; https://www.iea.cc) as a specialization of human factors/ergonomics (HFE). 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." Classical topics in CE include cognitive task analysis and modeling, decision making, information presentation and visualization, and mental workload and work stress. The definition at least partly incorporates HFE's general key characteristics, which are, according to Dul et al. [5], a general system approach (systems consist of humans and their environments), a design-driven approach, and a focus on two joint design outcomes: well-being of the human and performance of the system. However, the current definition insufficiently reflects changing understandings in CE. Three aspects can be discerned here.

First, the unit of analysis has expanded from predefined cognitive tasks to practical collaborative

Our understanding of the field needs to be updated to take CE out of particular work settings, such as cockpits and control rooms, and into day-to-day culture and the wider environment.

activities. Corresponding changes in the methodological approaches have been influenced, for example, by the workplace studies of computer-supported collaborative work (CSCW) and by alternative theoretical approaches to cognition, such as situated cognition and activity theory. New aspects to be studied include communication and coordination in collaborative activities and situational awareness.

Second, CE is generally design driven. Earlier approaches tended to be corrective ones, in which existing systems and their design were analyzed and deficiencies repaired. CE's focus is now more balanced between repair and novel design. Current approaches often take a more active role, involving users and other stakeholders from the earliest design stages onward, not only to prevent design pitfalls but also to create new ideas for the designed object. One influence in CE that is not emphasized in HCI is organizational ergonomics, which considers the interplay between individuals, collectives, and organizations.

Third, the understanding of work systems and computing systems has been expanded. In our current society, designing for use is needed for a broader spectrum of application domains, including public services, education, and learning, as well as domestic and leisure environments. CE approaches are now applied to the design of interactive art and the design of individualized participation in cultures and access to cultural heritage. In general, state-of-the-art CE allows a broader focus on interaction with artifacts, from usability to individualized experience of use.

We have experienced how consumer products, whether smartphones and Internet-accessible pacemakers or sports watches, as well as services such as social media and payment services, are entering the personal sphere. The increasing use of technology in everyday life may trigger a revision of current understandings of well-being, as well as cognitive and system performance (and their optimal compromise—an objective in HFE).

CONVERGING DISCIPLINES?

CE and HCI thus far have evolved as parallel but overlapping developments in relating human to machine, in which HCI started with the machine, whereas CE started from inside people's heads. CE's difference from HCI is, according to Bill Papantoniou [6], "mainly the broader focus of the analysis to include the work system as a whole, as opposed to the user-computer interaction, as well as other factors (organizational, history, etc.) that traditional HCI often avoids addressing, and hides under the 'context' label instead." As an example of a typical CE approach: Designing safety-critical work will start from a functional model of the situation and the organizational context of the operators, and an analysis of the required operations. Artifacts to be designed will shape the operators' cognition and collaboration. Consequently, design, theory building, and experimenting with envisioned solutions will be iterative phases in CE practice. This approach is applied, for example, in the design experiment in [7] aimed at creating technical support specifying what protective equipment firefighters need to wear in a chemical-spill emergency. Compare this with the above-mentioned HCI approach toward the design of usable systems that starts by analyzing successful designs. The study in [7] also illustrates a use of prototypes as "tools of discovery" [8], which is typical for many CE studies. Here, prototyping helps to investigate how cognition and collaboration is shaped by the aiding concepts that are embodied in the prototype [8]. In contrast, HCI and user-centered design approaches are dominated by a product-oriented view on prototypes. They are understood as partial design representations of the final digital artifact or product. These differences between the CE and HCI approaches show the practical value of the CE methodology.

Despite the above points, for some time the scope, concepts, and methods of HCI and CE have been moving closer together. For instance, an increased understanding of the complexity of systems and the need for interdisciplinary design work is common between HCI and CE. In HCI, we see the development of a more systemic view on interactional spaces. Converging from the other direction, concepts such as value of use and user experience, known from HCI and interaction design, are becoming relevant in CE. Both HCI and CE together need to revise their understanding of users' needs (HCI jargon) and well-being (CE jargon) to better respond to new demands due to, for example, continuing automation, current consumption behavior, and an overuse of resources.

Given that CE and HCI are potentially converging, what is the role of CE in this process? Compared with the ECCE meetings that attract under 100 participants, ACM SIGCHI has around 3,000 participants from different continents in the largest conference. EACE is now one of the SIGCHI communities. Since HCI is so much larger than CE, why can't HCI simply absorb the activities of CE?

James March, in his article on the evolution of research communities [3], points out that integration across scientific disciplines generally has increased. Integration helps to establish cross-relations, to unify understandings, and to develop, refine, and exploit existing knowledge and methods. However, March calls for a balance between integration and fragmentation processes. We also need boundaries of different forms to avoid domination relationships and long-term stagnation: "Disciplinary, linguistic, geographic fragmentations interfere with the consolidation of a clear paradigm, but they encourage both experimentation and persistence with new ideas. Differentiated enclaves of knowledge simultaneously resist the homogenizing tendencies of dominant groups and sustain new beliefs against further originality long enough to explore them fully" [3].

EACE is a geographic research community that is arising from the varieties of European research cultures and approaches to understanding and shaping human use of technology. It provides a viable space for exploring and positioning new ideas through having intensive discussion and cultural exchange. CHI conferences seem now to be very much focused on tenure-track publications and there are many parallel tracks, with a subsequent reduced presentation length and less discussion. ECCE conferences are important in complementing these other conference formats; participants appreciate the intensive and wide-ranging interactions between young and experienced researchers and

practitioners. Such interactions support an appreciation and critical appropriation of existing knowledge and traditional methods of investigation and research. They also trigger creativity, such as in identifying new application domains for CE, in applying new techniques for design, in identifying new opportunities, and in broadening the awareness of values that trigger acceptance and use. Interactive art is an example of a new domain of practice that benefits from CE's long history of discussion and critique, because the societal values behind interactive art are crucial to its social significance. Yet those values are contentious because they differ between geographic cultures and between stakeholders (artists, the art market, audience).

THE FUTURE

While CE and HCI both share a primary interest in research, in the past they have had different emphases. Now researchers in the two disciplines find that each offers attractive aspects that the other previously downplayed. HCI is becoming more interested in the nature of processes, such as cognition, collaborative working, and sociotechnical systems. It is also returning to its roots in human factors. CE is developing toward the making of artifacts and toward a greater focus on impact for industry and consumers, such as user experience.

The two disciplines also have a natural common interest that should lead to greater linking between the two, which concerns policy. As there is an increased interest in ethical technology in both HCI and CE, the two groups should have discussions about privacy and data-power inequalities, including how privacy should be vouchsafed as well as whether and how platform providers should be regulated. All this makes sense, as we see the world as more interconnected and issues appear in a sustainable light.

Thus, the two disciplines can and should contribute to how each is taught. Education of future technologists should not be limited to computer scientists, but rather should be considered holistically, as part of data science, public administration, and policy studies. How we now gather and use data is inextricably a part of human-computer interaction, as well as being essentially relevant to well-being and cognitive ergonomics. This vision needs to be spread via public engagement, so that both young and old understand that computers and technology are a part of life, and that we humans are not separate or distant from these artifacts and their role in human activity.

Finally, EACE is a community in SIGCHI. There is, and should be, interactions and greater linking between large and small groups—whether in the form of discussions or shared working groups. But CE is different from HCI: CE does not primarily aim to contribute to research, education, and practical application of HCI, as SIGCHI states on its website. EACE aims at the development of theory and education, and the practice of the design of complex systems in organizations, arts, leisure, education, industry, and services. The core of CE is focused on the effect of designing artifacts (which could be social structures, tools, rules, knowledge, representations) on cognition, and on related development and change. Consequently, there is an opportunity for mutual benefit: EACE and CE will continue to be inspired by and learn from new design ideas and products from HCI. And HCI may benefit from theoretical developments and rigorous multidisciplinary system modeling from CE.

ACKNOWLEDGMENTS

We thank our fellow EACE Executive Committee members, Assaf Botzer, Marja Liinasuo, and Maurice Mulvenna for their valuable comments.

ENDNOTES

1. http://www.eace.net: website of the European Association of Cognitive Ergonomics (EACE) with links to the ECCE Conferences series and all proceedings. ECCE '82 initiated the foundation of the EACE, and, in fact, coined the label and originally defined the field of cognitive ergonomics. ECCE proceedings have been published in the ACM Digital Library since 2006 (see https://dl.acm.org/doi/proceedings/10.1145/3335082 for the ECCE '19 proceedings).
2. The proceedings of the workshop "Rethinking Cognitive Ergonomics" at ECCE '19 are published at http://ceur-ws.org/Vol-2539/.

3. March, J.G. Parochialism in the evolution of a research community: The case of organization studies. *Management and Organization Review 1*, 1 (2004), 5–22.
4. Carroll, J. and Campbell, R. Artifacts as psychological theories: The case of human-computer interaction. *Behaviour & Information Technology 8*, 4 (1989), 247–256.
5. Dul, J., Bruder, R., Buckle, P., Carayon, P., Falzon, P., Marras, W.S., Wilson, J.R., and van der Doelen, B. A strategy for human factors/ergonomics: Developing the discipline and profession. *Ergonomics 55*, 4 (2012), 377–395.
6. https://www.interaction-design.org/literature/book/the-glossary-of-human-computer-interaction/cognitive-ergonomics
7. Norros, L., Liinasuo, M., and Hutton, R. Designing tools for emergency operations: New method of parallel augmented exercise. *Proc. of the 28th Annual European Conference on Cognitive Ergonomics*. ACM, New York, 2010, 49–56.
8. Woods, D.D. Designs are hypotheses about how artifacts shape cognition and collaboration. *Ergonomics 41* (1998), 168–173.

Anke Dittmar is an associate professor at the University of Rostock, Germany. Her research interests include user-centered design methods, design representations, collaborative design activities, and empirical studies of artifact use. She is the current president of the EACE.
→ anke.dittmar@uni-rostock.de

Dianne Murray has been active in the HCI field since 1979. As a research scientist in a U.K. government laboratory, she carried out early work on adaptive intelligent interfaces. A longtime educator in HCI, she is an experienced usability consultant. She is also a previous president of EACE.
→ dmm410@gmail.com

Gerrit C. van der Veer developed HCI education at universities in the Netherlands, Romania, Spain, Italy, and China. He is emeritus professor at the Vrije Universiteit Amsterdam (Netherlands), professor of Multimedia and Animation at the Luxun Academy of Fine Arts (China), and professor of Interaction Design at the Dalian Maritime University (China).
→ gerrit@acm.org

Harry J. Witchel is discipline leader of physiology on the University of Sussex site of Brighton and Sussex Medical School. His team researches the interplay between cognitive engagement and human movement for mitigating the effects of boredom and mind wandering in order to improve work performance and study.
→ h.witchel@bsms.ac.uk

DOI: 10.1145/3447792