Do Cyborgs dream of Electric Limbs? Experiential Factors in Human-Computer Integration Design and Evaluation

Valdemar Danry
MIT Media Lab
Cambridge, MA, United States
vdanry@mit.edu

Pat Pataranutaporn
MIT Media Lab
Cambridge, MA, United States
patpat@mit.edu

Adam Haar Horowitz
MIT Media Lab
Cambridge, MA, United States
adamjhh@mit.edu

Paul Strohmeier
Saarland University
Germany
strohmeier@cs.uni-saarland.de

Josh Andres
IBM Research & Monash University
Melbourne, Australia
josh.andres@au1ibm.com

Rakesh Patibanda
Exertion Games Lab, Monash University
Melbourne, Victoria, Australia
rakesh@exertiongameslab.org

Zhuying Li
Exertion Games Lab, Monash University
Melbourne, Victoria, Australia
zhuying@exertiongameslab.org

Nathan Semertzidis
Exertion Games Lab, Monash University
Melbourne, Victoria, Australia
nathan@exertiongameslab.org

Takuto Nakamura
Tokyo Institute of Technology
Tokyo, Japan
nakamura.t.by@m.titech.ac.jp

Jun Nishida
University of Chicago
Chicago, IL, United States
jun.nishida@acm.org

Pedro Lopes
University of Chicago
Chicago, IL, United States
pedrolopes@uchicago.edu

Felipe León
University of Copenhagen
Copenhagen, Denmark
felipe.leon@hum.ku.dk

Andrea Stevenson Won
Cornell University
Ithaca, NY, United States
asw248@cornell.edu

Dag Svanæs
Norwegian University of Science and Technology
Trondheim, Norway
dag.svanes@ntnu.no

Florian 'Floyd' Mueller
Exertion Games Lab, Monash University
Melbourne, Australia
floyd@exertiongameslab.org

Pattie Maes
MIT Media Lab
Cambridge, MA, United States
pattie@media.mit.edu

Sang-won Leigh
Georgia Institute of Technology
Atlanta, GA , United States
sang.leigh@design.gatech.edu

ABSTRACT

While many systems have successfully demonstrated functional integration of humans and technology, little attention has been paid to how technologies might experientially integrate to feel as part of humans. Our aim is to shed light on the importance of experiential integration and provide researchers with a scientifically driven foundation for future designs and investigations. The workshop will consist of hands-on experiments with novel body-illusions, discussions on experiential integration, and instructor-guided sessions on psychological concepts related to the design and evaluation of experiential integration.

CCS CONCEPTS

• **Human-centered computing → Interaction paradigms**; **HCI theory, concepts and models**.

KEYWORDS

human-computer integration, human augmentation, experiential integration, sense of self, sense of body-ownership, sense of agency, cognitive science, phenomenology

ACM Reference Format:
Valdemar Danry, Pat Pataranutaporn, Adam Haar Horowitz, Paul Strohmeier, Josh Andres, Rakesh Patibanda, Zhuying Li, Nathan Semertzidis, Takuto Nakamura, Jun Nishida, Pedro Lopes, Felipe León, Andrea Stevenson Won, Dag Svanæs, Florian 'Floyd' Mueller, Pattie Maes, and Sang-won Leigh.

CHI '21 Extended Abstracts, May 8–13, 2021, Yokohama, Japan

ACM ISBN 978-1-4503-8095-9/21/05.
https://doi.org/10.1145/3411763.3441355

2021. Do Cyborgs dream of Electric Limbs? Experiential Factors in Human-Computer Integration Design and Evaluation. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts (CHI '21 Extended Abstracts), May 8–13, 2021, Yokohama, Japan.* ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/3411763.3441355

1 INTRODUCTION

Recent developments in Human-Computer Interaction research mark a new paradigm shift from interaction to integration of devices with the human body. Instead of considering human and computer as two separate entities, the research area of Human-Computer Integration aims at incorporating computers as "part of" the user to enhance their physical or cognitive capabilities [2, 27, 29].

Imagine, for instance, an exoskeleton that actuate a user's body to execute precise motor movements. Such a wearable exoskeleton can, therefore, allow this user, who has never touched a piano, to play at a professional level. This is similar to the goal of prosthesis in the domain of medical rehabilitation, which aim at assisting amputees completely regain or exceed pre-amputation functionality. What is unique about this paradigm is the idea of technology becoming **integrated** with the human body, in contrast to being a 'tool' that is consciously controlled by a person, or being an autonomous system that does not have a human in the loop (see figure 1). Integrated systems are aiming for a fundamentally different experiential goal compared to traditional HCI systems, that is, the sense of "I did that with my[self]" rather than "the machine did that for me" or "I did that with the machine" [16, 27].

In spite of new opportunities for increasing human performance, accessibility, and experience overall, we see limitations in current research on Human-Computer Integration. First, research on Human-Computer Integration is mostly a technical enterprise in that it is primarily concerned with the 'physical form-factor' and 'performance measures' of integration. However, for humans to successfully integrate with computers it is not sufficient to only think about 'physical integration'. An exoskeleton might for instance be able to move a user's fingers to make their body play the piano effortlessly while still not providing them with a sensation that those actions were "done by me"[33], or a prosthetic limb might help the user to walk effortlessly while not providing the user with a sensation that "the prosthesis is part of me" [28]. If we are to experience the computer as "part of us", we must therefore also consider 'experiential integration', that is, how a technology might be experienced as a natural part of the user's body.

However, when evaluating integration, most researchers have focused on changes in users' reflective self-perception or judgement of an integration as part of their body, e.g. their "relational self" [27], "body-image"[19, 20] and "self-image" [5] while overlooking the pre-reflective aspects of body-experience [10, 11, 18], i.e. the pre-reflective sense of body-ownership and agency which are felt without requiring explicit observation and reflection [34]. Phantom limb patients are an example of this, as they are reflectively aware that they are missing a limb (i.e., it is not part of their self-concept or body image) while they still 'pre-reflectively' feel a phantom limb being part of their body. A system designed only to satisfy users' reflective self-perception will thus utilize a too narrow understanding of body-experience which in turn might result in particular limitations and risks. Therefore, researchers should address pre-reflective aspects of experience in their designs and evaluations of experiential integration.

As a result, this workshop pursues an exploration into eliciting a sense of self over an integrated technology with respect to how HCI systems are designed. We revisit existing neurocognitive, phenomenological and Human-Computer Integration research to identify and articulate these gaps in theoretical and methodological approaches, in particular the experiential layer of designing Human-Computer Integrated systems. The workshop will provide hands-on experience with the concepts involved in experiential integration, through exercises that explore aspects of bodily experience such as *reflective-* and *pre-reflective body-awareness* [18], *sense of body-ownership* [23] and *sense of agency* [7] inspired by and designed in collaboration with artist Carsten Höller [12] and previous work of the organizers [1, 14, 16]. These activities will allow us to pin-point certain factors that are relevant for experiential integration, and help us formulate a conceptual landscape, future design space and evaluation paradigms of first-person experiences of integration.

2 GOALS OF THE WORKSHOP

The workshop's primary goals are: (1) to serve as an enduring community and discussion platform for researchers whose work focuses on the technologies that impact "self-hood"; (2) articulate the first-person aspects of self-integrated systems in forms of experience and examples; (3) understand forthcoming issues of designing and evaluating self-integrated systems; (4) discuss the ethical implications of integration with technology; (5) consider experiential boundaries, fragility of self-concept, disorders in which pre-reflective awareness and derealization are implicated, and (6) extend the collaborative research and community engagement through building new research programs.

Major topics discussed in the workshops include:

Theory of experiential integration In the following sections, we articulate key concepts from neurocognitive and phenomenological sciences that are imperative in investigating aforementioned systems. We discuss the importance and impact of experiencing a pre-reflective "Sense of Body-ownership" and a "Sense of Agency" over a body-integrated computer to identify different conditions that a system should meet in order to provide an *experiential integration.*

Designing for experiential integration The workshop discusses conditions that are imperative in designing and experimenting with technologies that experientially integrate with users. Integration with the body is not always a guarantee for an artifact being experienced as integrated with the user. In fact, some prosthetic users do not experience their prosthetic as a part of their phenomenal body despite also being "successful users" [28].

> "Using a prosthetic is not a natural thing, because a prosthetic is not a substitute leg, it is a tool which may or may not do some of the things that a leg might have done. If I want to walk again (which I do, very much) I have to do this, I can't emphasize enough that it is a practical issue." [27]

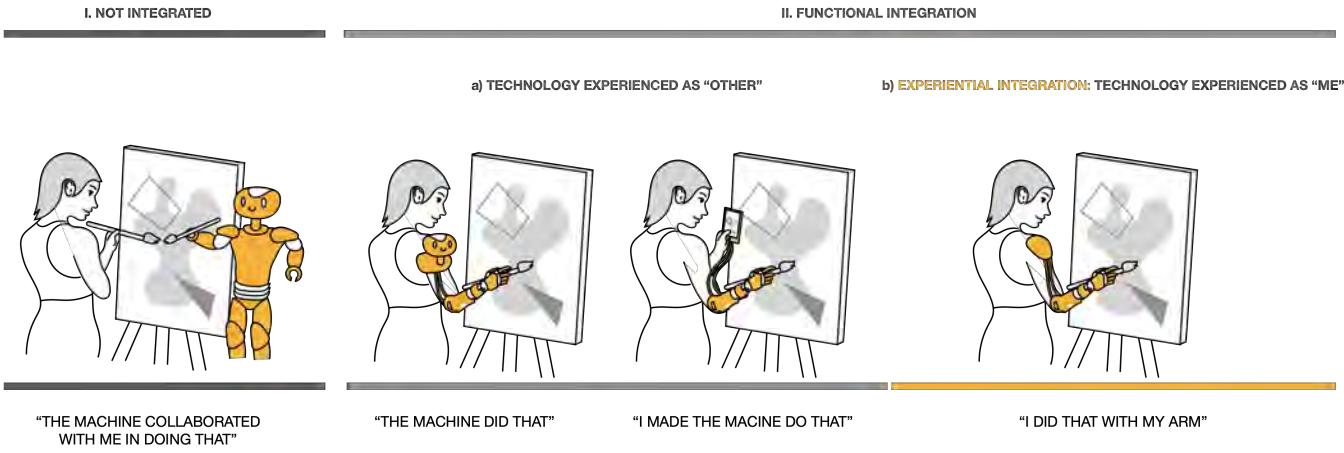

Figure 1: For a physically integrated technology to feel as "me" instead of something "other", we have to progress towards experiential integration, i.e. systems that afford a sense of "I did that myself" rather than "The machine did that" or "I made the machine do that".

Through experiments, we discuss various experiential factors that are essential in the design of Human-Machine Integration system. The workshop will collaboratively design an "Experiential Integration Cookbook" that lists micro-experiments and factors that contribute to the sense of self with technology.

Evaluating experiential integration We also need tools to measure and evaluate the pre-reflective senses of ownership and agency and how they occur or diminish in the conscious experience of the users. We aim at deriving novel study and interview methods, drawing inspiration from contemporary phenomenological research.

3 PRE-WORKSHOP PLAN

The workshop will be driven by cross-disciplinary researchers with practical experience in integrated human and computer technologies and research experience focusing on the sense of self. Questions of experiential integration touch on a wide range of fields and we will look to each for inspiration, as workshop hosts have backgrounds ranging through neuroscience to HCI to the arts.

Neuroscience and cognitive science provide a rich theoretical background for questions of agency. EEG experiments demonstrate scientists can predict motor movements of subjects multiple seconds before their own subjective experience of decision-making occurs, forcing questions of organic agency and free will [3]. Studies show that disruptions in sense of agency over our own movements occurs naturally immediately following wakeups from REM sleep, leading to the strange experience of being able to tickle oneself as motor predictions and self-other distinctions break down [4]. This failure of sensory prediction and concomitant disruptions of sense of motor agency is also seen in schizophrenia, where patients with a fragile sense of self are able to self tickle [31]. Alien Hand Syndrome, seen after the corpus callosum is surgically cut and the brain hemispheres separated, manifests in fascinating clinical cases where two hands on one person exhibit different goals [9].

We must bring these movement-based experiences which cause us to question the sense of self out of the clinic and laboratory, if they are going to inform real-world technology development. The organizing team will discuss movement-based experiences and mini-experiments to be performed with workshop participants in the form of theater games. These experiments will be informed by the work of organizers; work by workshop host Pedro Lopes mirrors this alien hand using HCI, taking control of motor movements using portable electrical muscle stimulation devices [22]. Takuto Nakamura and colleagues explored a simple yet elegant motor-illusion called wire hanger illusion in order to create the feeling of limbs drifting [25]. Other organizers have explored various novel interfaces including wearable robots, edible interfaces, motor memory support, epidermal interfaces and more [8, 17, 21, 24, 26, 32]. Furthermore, Carsten Höller, a renowned installation artist and expert on bridging art and science for experimental phenomenology [13], has agreed to consult on the development of artistic games to modulate a sense of self. We will look to the arts, and to real world HCI applications, to create work at the phenomenological level to engender experiences which raise questions. The theater games are modified to be doable from home so that they fit the "online" format of CHI2021.

4 ORGANIZERS

Valdemar Danry is a visiting student at MIT Media Lab from the University of Copenhagen in Denmark. His passion is the intersection between philosophy, technology and arts, more specifically the relationship between technology and consciousness. With his background in phenomenology, psychology, computer science, philosophy, and art, he seeks to explore how the augmented body mediates experiences of the world not just as something physical but as something which is "lived".

Pat Pataranutaporn is an antidisciplinary technologist / scientist / artist at the Massachusetts Institute of Technology. He is a PhD student in the Fluid Interfaces research group at MIT Media

Lab, which specializes in designing on-body technology for human enhancement. Pat's research is at the intersection of biotechnology and wearable computing, specifically at the interface between biological and digital systems.

Adam Haar Horowitz is a PhD student at MIT Media Lab. His research focuses on when cognitive science steps outside the lab to create new interventions, stories, and unseen connections between siloed peoples and vocabularies. He think talk is not so cheap, science is art, and things get stale if the doors aren't flung wide. He is especially interested in wellness and wonder.

Paul Strohmeier is a postdoc at the HCI group of Saarland University. He is interested in human perception and computer sensing. He applies methods from psychophysics to deepen his understanding of human perception, especially in relation to action.

Josh Andres is a researcher and designer at IBM Research Australia and the Exertion Games Lab at Monash University whose goal is to investigate and design intelligent like systems that enable human potential.

Rakesh Patibanda is a PhD candidate at the Exertion Games Lab, Monash University. His current research lies at the intersection of technology, body and play aiming to understand the design of memory support systems in HCI.

Nathan Semertzidis is a PhD candidate at Exertion Games Lab, Monash University. His research investigates how neural interfaces can be designed to facilitate integration between humans and computers, and from brain to brain.

Zhuying Li is a final-year PhD candidate at Exertion Games Lab, Monash University. Her research focuses on the intersection of technology, human, and play. She is currently working on interaction design with ingestible sensors.

Takuto Nakamura is a postdoctoral fellow of the Japan Society for the Promotion of Science and belongs to Koike Laboratory at Tokyo Institute of Technology. He is interested in controlling human behavior using force perception. Especially, he has been working on the development of a device using a haptic illusion called "Hanger Reflex" which induces strong force sensations.

Jun Nishida is a postdoctoral fellow at the University of Chicago and a research fellow of Japan Society for the Promotion of Science. He is interested in designing wearable cybernic devices that share one's embodied and social experience among people by means of electrical muscle stimulation, exoskeletons, and virtual/augmented reality systems.

Felipe León is an Assistant Professor at the Center for Subjectivity Research, University of Copenhagen. León's primary research areas are classical phenomenology, theories of selfhood, social cognition, and collective intentionality. Publications include "For-meness, For-us-ness, and the We-relationship", "Phenomenology of experiential sharing: The contribution of Schutz and Walther", and "How We feel: Collective Emotions Without Joint Commitments".

Pedro Lopes is an Assistant Professor in Computer Science at the University of Chicago. Pedro focuses on integrating computer interfaces with the human body—exploring the interface paradigm that supersedes wearable computing. Some of these new integrated-devices include: a device based on muscle stimulation that allows users to manipulate tools they never seen before or that accelerate their reaction time, or a device that leverages the sense of smell to create an illusion of temperature. Pedro's work also captured the interest of media, such as New York Times or NewScientist, and was exhibited at Ars Electronica and World Economic Forum.

Andrea Stevenson Won directs the Virtual Embodiment Lab at Cornell University. She focuses on how mediated experiences change people's perceptions, especially in immersive media. Research areas include the clinical applications of virtual reality, and how nonverbal behavior as rendered in virtual environments affects collaboration and teamwork.

Dag Svanæs's research over the last 15 years has been in the fields of HCI and Interaction Design. His main focus has been on user-centered design methods and basic theory of interaction. At a practical level this involves a focus on the physical, bodily and social aspects of interaction. In his research he makes use of role play and low-fidelity prototyping in realistic settings to involve end-users in the design process.

Florian 'Floyd' Mueller is a professor at Monash University, where he directs the Exertion Games Lab. His research straddles the intersection of human-computer integration and play. He has co-organized 9 workshops at CHI previously and was general co-chair CHI'20.

Pattie Maes is a professor in MIT's Program in Media Arts and Sciences and until recently served as academic head. She runs the Media Lab's Fluid Interfaces research group, which aims to radically reinvent the human-machine experience. Coming from a background in artificial intelligence and human-computer interaction, she is particularly interested in the topic of cognitive enhancement, or how immersive and wearable systems can actively assist people with memory, attention, learning, decision making, communication, and wellbeing.

Sang-won Leigh is an assistant professor at Georgia Tech. Sang's research and art practice focuses on robotic and computational tools that essentially become a natural extension of our hands. This way, he challenges the fear and criticism around AI and automation that they replace human endeavors, by showing how symbiotic machines can unlock new human explorations and aesthetics.

5 WORKSHOP WEBSITE

http://cyborgdreams.media.mit.edu/

6 WORKSHOP STRUCTURE

The workshop will take place over a full day (4 hours). Main workshop activities include hands-on exercises on "experiencing experience" of an alternative body condition, research presentation by volunteering participants, and a collective discussion on an *experiential integration cookbook*. A tentative timeline is described below:

- Opening and Keynote (45 minutes)
- Experiential Integration Introduction (30 minutes)
- Break (15 minutes)
- Exercise Part 1 (30 minutes)
- Exercise Part 2 (30 minutes)
- Break (15 minutes)
- Participant Research Presentation (1 hour)
- Cookbook Discussion (45 minutes)
- Break (15 minutes)
- Summary, future directions, closing (45 minutes)

Prospective participants may apply to join the workshop through the workshop webpage (see the previous section) or by invitation by the organizing team. The application will enquire their fields of research, particular topics within embodied cognitive science they are interested in, and future research questions. The workshop team will review each application and select the final list of participants based on the alignment of research topics, background, academic diversity, and potential to bring new perspectives to the workshop.

6.1 Experiencing Experience Exercises

In order to introduce the various aspects of experiential integration, the workshop will consist of particular activities and techniques which modulate (i) Reflective and Pre-reflective Self-awareness, (ii) Sense of Body-ownership, and (iii) Sense of Agency. The exercises design wil be based on the works of organizers and artist Carsten Höller who is known for the "Upside-down Glasses," that is a scientifically driven art experience exploring the modification of visuo-motor experience.

Reflective and Pre-reflective Self-awareness To show the distinction between reflective and pre-reflective body-awareness, we will utilize a "Mirror Tracing Task" [15]. In a mirror tracing task, the participants will use a pen to follow a line from one end to the other (while the line twists and turns) only using a mirror. The participants are unable to see their own hand directly and thus have to use the mirror to coordinate their body movements. This forces the participants to rely on a reflective awareness of their hand to coordinate movements — and thus it acts as an example of the contrast between implicit pre-reflective body-awareness and reflective body-awareness in normal healthy individuals.

Sense of Body-ownership and Agency To exemplify sensation of body-ownership, we will utilize variations of the "Rubber hand illusion" [34] and "sixth finger illusion" [6]. These experiments explore an alternative limb being felt as a part of oneself. Specifically, the experiments will be designed to be progressively experienced as a part of one's body through various techniques such as visuo-tactile induction, moving from reflective to pre-reflective senses of ownership. We will contrast the sense of agency from ownership through another set of experiments. For instance, the wire hanger illusion[30] will be used to illustrate an illusory force or reflex when one wears a wire hanger on the head. Through a sequence of task, participants will grow from reflectively conducting motor tasks towards pre-reflectively completing those.

7 POST WORKSHOP PLAN

With the discussion from the workshop, we aim at proposing a follow-up workshop either online, hosted at an institution of one of the workshop organizers, or at Dagstuhl in the following year. We expect the follow-up workshop to focus on specific sub-themes e.g. ethical implication of integration technologies on human minds, experiential inquiry of self-awareness in the arts, and so on. The documentation of the experiment sessions and experiential integration discussion are planned to be submitted to a related academic journal (TOCHI, IMWUT, IEEE Pervasive or ACM Interactions). We will also establish a continuing platform for researchers to discuss and collaborate in forms of Slack channels or mailing lists, where researchers on related topics could continue to join. The details of these follow-up activities as well as the open platform will be announced on the workshop website.

8 CALL FOR PARTICIPATION

The workshop *Do Cyborgs Dream of electric Limbs?* focuses on the prospective of Human-Computer Integration, and discuss the matters of human factors, cognitive science, and ethical considerations around the topic. Cognitive and psychology research reveals different levels of body awareness and how these can be induced or designed upon. We focus on how to realize and evaluate *experiential integration* with technology. While many systems have successfully demonstrated *functional integration* of humans and technology, little attention has been paid to the experiential sense of self in such integration, in particular, how an integration might feel as part of the user.

The workshop discusses the idea of experiential integration, align it with evidence from cognitive science, and discuss its implications for Human-Computer Integration design and evaluation. The workshop activities consist of hands-on experiments with novel body-illusions, discussions on an experiential integration cookbook, and instructor-guided sessions on how to design and evaluate experiential integration for each participant's research topics.

If you are interested in the workshop, please submit your application through:

https://forms.gle/i4HBPZuYdpWnthQS9.

The submission deadline is February 7th, 2021. We will notify the accepted participants by the end of February, 2021 and with a maximum of 30 participants. The list of participants will be posted on the workshop website:

http://cyborgdreams.media.mit.edu

Accepted participants should attend the workshop and must register for both the workshop and for at least one day of the conference.

ACKNOWLEDGMENTS

We thank artist Carsten Höller for his willingness to collaborate on designing the workshop activities.

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