Body-Centric Computing: Results from a week-long Dagstuhl seminar in a German castle

Florian 'Floyd' Mueller
Exertion Games Lab, RMIT University, Australia
floyd@exertiongameslab.org
Josh Andres
Exertion Games Lab, RMIT University & IBM Research, Australia
ja@exertiongameslab.org
Jo Marshall
University of Nottingham, UK
joe.marshall@nottingham.ac.uk
Dag Svanæs
Norwegian University of Science and Technology, Norway
dags@idi.ntnu.no
m.c. schraefel
University of Southampton
mc@ecs.soton.ac.uk
Kathrin Gerling
KU Leuven, Belgium
kathrin.gerling@kuleuven.be
Jakob Tholander
Stockholm University, Sweden
Jakobth@dsv.su.se
Anna Lisa Martin-Niedecken
Zurich University of the Arts
anna.martin@zhdk.ch
Elena Márquez Segura
University of California, Santa Cruz, USA
elena.marquez@ucsc.edu
Elise van den Hoven
elise.vandenhoven@uts.edu.au
Nicholas Graham
Queen's University, Canada
nicholas.graham@queensu.ca
Kristina Höök
Royal Institute of Technology, Sweden
khook@kth.se
Corina Sas
Lancaster University, UK
corina@comp.lancs.ac.uk

Introduction

In late 2017, 23 researchers and academics from Europe, Australia and the USA gathered for a week to discuss the future of body-centric computing. Dagstuhl, a non-profit center for computer science research, which is located in a rural area in Germany and provided the workshop space in an 18th-century picturesque castle, hosted the seminar.

The goal of the seminar was to discuss the future of what it means to design interactive technology when centering on the human body and the future of this novel area of interaction design. This area evolved in part with the emergence of movement-, physiological- and bio-based sensors and actuators, to which followed the blooming of technologies such as wearables, quantified-self systems and movement-based interactive systems (e.g. exertion games). These technologies bear a close relationship to the body: they may be worn (wearables), carried and kept close to the body (mobile technology) or involve body movements or physiological responses as main interaction modality (e.g. exertion games, quantified-self systems). They stand in stark contrast to technologies and applications within the previously prevalent desktop computing paradigm, which involved interacting with computers in a way that required minimal bodily engagement and rather static positions, such as sitting still. The motivation for the seminar stemmed from the realization that until today, most work in this area has taken mostly an instrumental perspective, focusing on achieving objectives, such as "who jogged the most miles this week?" rewarding athletic performance. However, theories and perspectives, such as phenomenology and user experience design, can help us extend this focus on performance to also include the subjective embodied experience of the user engaged in such interactions.

Despite the concept of embodiment having been in the spotlight in Human-Computer Interaction, the body, the actual corporeal, pulsating and felt body, has been notably neglected in theory and design work. This may be because we lack knowledge and vocabulary to access, articulate, and ultimately design for these highly subjective and elusive bodily experiences that go beyond external sensorial interactions. The challenge further increases when a key design material comes from a vast amount of data reported by various sensors. Another issue is that HCI researchers typically have limited direct knowledge of or training in how the body works as a complex system (i.e. in-bodied knowledge). In order to drive such an agenda that supports instrumental as well as experiential, embodied, and in-bodied perspectives of the active human body, the seminar brought together leading experts. They discussed key questions around the use of interactive systems to support both instrumental and experiential perspectives to pioneer new approaches for what we propose to frame as *a future of body-centric computing*.

The aim of body-centric computing is to design products and services that reposition the role of the body from periphery to the centre of the interaction, becoming body-friendly. This means solutions that seriously consider, respect, extend, enhance or facilitate the user's body and associated bodily experiences. This contrasts solutions that ignore, neglect and disregard the role of the body to perceive, act, and construct meaning: in short, to *be* in the world.

The core application domains for body-centric computing are *health*, *wellbeing*, *sports* and *entertainment*. The *Health* domain includes prevention, rehabilitation, disease management and cognitive/physical performance. *Wellbeing* supports pleasure and connectedness, or uses embodied interaction to facilitate cognitive offloading. *Sports*, including insights from sport science, view the body as a site for performance, training, learning, and improvement. *Entertainment*, including gaming, aims for full bodily immersion in interactive experiences.

The seminar began with talks by all attendees, in which they presented their work in the area, the theoretical perspectives that guide their work, and a description of their most and least favorite body-centric computing projects. After the presentations concluded, no more slides were used for the remainder of the week, with all activities being conducted either as a round table, standing up, or exercising both indoors and outdoors, fitting with the seminar theme. The program included group activities with supplemented whole-body movement practices to support a "brain as part of the body" approach. Optional morning and evening activities, such as playing golf, jogging, cycling, hiking, or slacklining further supplemented this use of the physical in support of the cognitive/social dimension. A selection of some key activities and methods, and the body-centric reflection they facilitated is outlined below to illustrate the seminar and its ethos.

1.1 Interactivity session

In an interactivity session, participants tried out each other's body-centric computing systems through hands-on experiences in order to reflect on the instrumental as well as experiential perspectives these designs actively supported.

Joe Marshall (University of Nottingham) set up a swing where users wear an HMD (head-mounted display) through which they see a virtual world that responds to the movement of the swing. This involved interesting mappings of action types in the physical world (swing) to the effects in the virtual world. This work elicited questions around how movement can be deliberately fed back to the user in an altered fashion to elicit novel entertainment experiences.

VR on a swing

Anna Lisa Martin-Niedecken from the Zurich University of the Arts presented her dual flow-based fitness game “Plunder Planet” [2] that adapts to players’ abilities in real-time, provoking questions around what role technology plays in allowing people to experience their bodies in an individual

and social context.

"Plunder Planet" cooperative multiplayer-setup at Dagstuhl

Lifetree by Patibanda et al. [4] is a VR game aimed to train a proper breathing technique. Participants who tried out the game said that their experience elicited reflection on the role technology can play in promoting wellbeing, while technology often raises challenges for health.

Florian 'Floyd' Mueller from RMIT University in Australia presented various headphones that use noise-cancelling, in-ear, over-ear and bone conducting technologies in order to raise the question of whether we could say that one is to be more body-centric than another.

Dag Svanaes from the Norwegian University of Science and Technology presented an interactive tail [5] that moves in response to the hip-movement of the user, controlled via sensors and actuators. This work elicited the phenomenological question about the role of technology in extending human bodies.

Dag Svanaes attaching the tail to Corina Sas

Perttu Hämäläinen from Aalto University in Finland presented his work on using AI to predict and animate movement in virtual worlds, provoking questions around how AI can inform the movement of embodied systems such as exoskeletons or the tail mentioned above and whether AI can accurately or evocatively represent human motion.

1.2 Methods for body-centric computing

Methods for how to design body-centric computing were not only heavily debated, but also tried out through design exercises. To better connect with our inner self and be able to access and use our bodily experiences in design, we engaged in several somatic sensitizing activities, led by Thecla Shiphorst (Simon-Frasier University, Canada). Some activities revolved around helping us alternate and work with different foci of attention. First, participants were invited to close their eyes to help them shift their attention to various body parts and somatic sensations, favoring a first-person

attentive inward-looking experience. To contrast this, other activities revolved around acting in the world without focusing on any object or people around, letting our attention diffuse as we moved in the world. In particular, we were to maintain this type of attention while walking very slowly through the surrounding forestry for about 20 minutes, in silence.

Walking very slowly through the surrounding forestry, in silence

This shared exercise of diffused attention aimed at an inward focus and a heightened awareness of the body in the world. It was done at a slow pace to allow the participants to use their bodies as a tool to access and as a site to cultivate their sensorial and felt experiences. The act of diffusing attention was later likened by participants to the type of cross-eye concentration required to see random dot autostereograms. After this exercise, participants were asked to pick three elements from their experience, which they would “imprint” in their bodies. This was done by focusing on

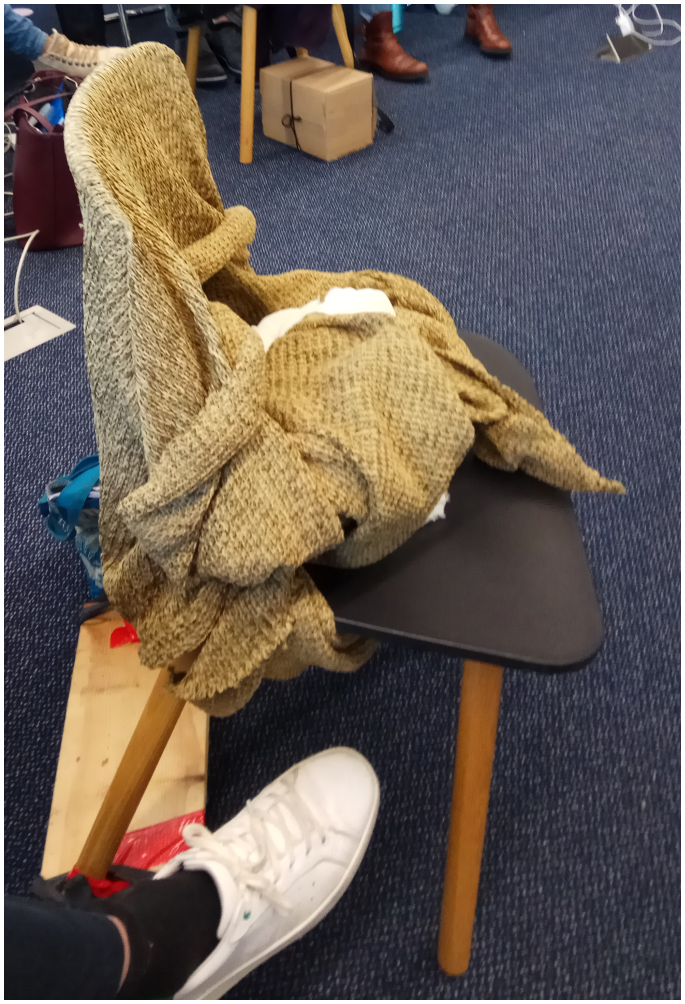
one particular element while gently pinching a part of one hand, using the index finger and thumb of the other hand. Participants placed on their bodies a tactile cue per experiential element selected. These bodily imprints where later accessed and utilized by participants in a group design task: designing an interactive shape-changing chair. These imprints were meant as lived experience inspirations, and as reminders of those elements, moments lived, and their bodily states. They were meant to transport participants to their previously lived state of slowness, appreciation, and cultivation, which can be inspirational body-centric design qualities.

Designing a chair without chairs

The design outcome, the chair, was not as important as the process itself. All the design teams realized how difficult it is to articulate felt experiences and applauded this bodily imprinting method in how it helped them articulate and agree on particular experiential qualities they wanted their design to elicit. The activity appeared to function as a way to gaining clear and focused design qualities.

Most participants appreciated the slow-walking-in-the-woods activity allowing them to get into a fruitful design conducive state. Many commented on how easy and quickly they decided on particular experiential qualities to design for, and how much in sync they felt within their design teams. Many related this to the prior bodily activity they all shared, which created an experiential common ground that facilitated internal communication and joint design work. Many speculated how slowly walking together in silence created a richer design vocabulary than a more traditional brainstorming or design discussion activity. This shared activity helped build a community and a sense of trust with one another, which helped materialize the collective experience in the design process (e.g. facilitating to take risks), and outcomes. Participants also noted that through the exercise, they were much more at ease combining things during the design phase that perhaps otherwise would have not made much sense if we were in a critical state, the “anything goes” state of mind is perhaps more productive than being “critical, smart, and the brilliant designer you always want to be”. However, for some participants the slow walking did not work that well; they

had difficulty not being goal-oriented, letting go and being in the moment. This shows that these activities might not work for everyone and in any state of mind, or that some people might require more time to appreciate such activities.



One of the design outcomes

In a critical examination and discussion about design outcomes from body-centered design processes, it was noted that they often fall into a “meditative,” “inward-looking,” “self-reflective" genre (e.g. the somaesthetic yoga mat [1]). Participants pondered about which types of sensitizing pre-design activities other types of aesthetic bodily experiences would require. If you are designing for a dance club, would slowly walking in the woods help and how? Likewise, what would happen if these designers had designed those chairs after jogging? It was also noted that this particular activity focused on designing from our experiences (i.e. the brief to design a chair was only given after the silence activity), whereas in reality, the brief usually comes first, hence the design process might therefore unfold differently.

Participants also observed that two lines of conversations emerged when reflecting on the activity; one was about designing for the human body from the lens of what is good for the human, while the second line is about designing new experiences that are experiential and not necessarily good for the human body; however, they do not necessarily need to stand in contrast, as Mueller and Young previously highlighted [3].

Participants also tried out taking on a first, second, and third-person perspective when designing for the human body [5]. The first-person perspective is concerned with the personal, felt perspective of the body, the second-person perspective is concerned with the interdependencies between bodies, whereas the third-person perspective is concerned with the external, more "objective" view of the body. Discussions that followed from this have highlighted that the third-person perspective is probably prevalent in most of today's available wearable technologies, with a few emerging systems also considering the first-person perspective. The second-person perspective is probably the hardest to grasp, with limited exemplars being available as guidance.

Collaborative working sessions at Dagstuhl

1.3 Open questions around body-centric computing

There are many open questions around body-centric computing. One particular open question that arose was how to articulate bodily experiences for design. At the moment, there is only limited knowledge of how to communicate, share and articulate bodily experiences. Following from here, we also acknowledge the need to understand how much knowledge about the human body one needs in order to design for body-centric computing. Of course, one might argue that the more the better, however, one position was that it is also impractical to expect all designers take kinesiology courses; others questioned if that is the case. Is there some basic knowledge that might be sufficient, or do we always need to bring experts in? For example, HCI curricula currently teach aspects of the vision system and Fitts' Law about our perceptual and performance capacities. Doesn't our new interest in body-centric computing not require us to add in more specific knowledge about other relevant physiological, chemical, hormonal, neurological processes? If so, how do we provide HCI students and designers with the necessary knowledge to draw from and interpret their own bodily experiences with confidence? Overall, there is a need for more methods and concepts for personalized and adaptive body-centric systems based on fine-grained knowledge of the human body.

Another question that emerged is how to respect experiences of body changes. For instance, how do we design for restricted movement? This question arose from the discussion around whether physical restriction could be used as a means to facilitate empathy for people living with physical disabilities.

Using VR to disrupt awareness of space to force relearning of how to navigate in the physical world.

In result, how can we design body-centric computing systems that affect movement, like physical restrictions, to facilitate limits across life course and experience? And how can designers create these experiences and ensure they are accurate (if they are meant to reflect a "real" experience)? Such an exploration could, for example, lead to exertion games in which the player starts off with a physical constraint like a distorted view that impacts orientation in the virtual world along with coordination of movement in the real world, and then through leveling up experiences increased empowerment. This progressive approach could be a way to design for transformation and development yet acknowledge that real-life strength and flexibility develops over months rather than individual exercise sessions, using technology to make this larger timespan more immediately visible and exploratory.

There are also many technical open questions around body-centric computing. A particularly pertinent one was detecting when people touch each other, and to what extent. Certainly, solutions already exist; however, they are often not very portable, requiring tethering and power. Developing systems that can unobtrusively sense human touch that are mobile and can be worn for long periods is still technically very challenging. Furthermore, a shortage of prototyping tools for body-centric computing is also limiting the field.

Finally, another important underexplored area concerns ethics around body-centric computing. Moving the body comes with certain risks, however, these risks have value in and of themselves, and interaction designers need to be aware of how to deal with this [3]. Participants argued that

the alternative is to design for stillness, which might not facilitate immediate injury, but ultimately leads to obesity and unhappiness, something that all participants aimed to avoid.

Acknowledgements

We thank Dagstuhl for their extensive support, all participants for contributing and picture taking.

Authors

Florian 'Floyd' Mueller is director of the Exertion Games Lab at RMIT University, Australia, where he engages body-centric computing to help facilitate personal growth. Previously, he was a Fulbright Scholar at Stanford University and has spent time at the MIT Media Lab, Microsoft Research, FXPal, Xerox Parc, University of Melbourne and CSIRO.

floyd@exertiongameslab.org

Josh Andres leads user experience and design at IBM Research Australia; his research in HCI investigates the interplay between a user's exertion and actuation enabled systems to facilitate new user experiences for the active human body. He is a PhD candidate at RMIT's Exertion Games Lab.

ja@exertiongameslab.org

Joe Marshall is a senior research fellow at the Mixed Reality Lab, School of Computer Science, Nottingham, UK. His work investigates games and artistic installations which respond to the user's full body. games Touch-o-matic and his Broncomatic breath controlled fairground ride were recently part of a long term installation at the UKs National Videogame Arcade. He also helped build, deploy and study VR Playground, a major touring VR artwork by artist Brendan Walker, which has been ridden by over 10,000 people in the last year.

joe.marshall@nottingham.ac.uk

m.c. schraefel university of Southampton – professor of computer science and human performance, as well as a certified strength and conditioning coach, nutritionist and movement coach. – m.c. leads the WellthLab in Human-Systems Interaction whose mission is: explore research and design of interactive computation systems to help #MakeNormalBetter to enhance quality of life for all.
mc@ecs.soton.ac.uk

Kathrin Gerling is an assistant professor at KU Leuven, Belgium, where she is part of the e-Media Research Lab. Her work broadly falls into HCI and physical computing. She is particularly interested

in how interfaces can be made accessible for audiences with special needs, and how interactive technologies can be leveraged to support well-being.

kathrin.gerling@kuleuven.be

Jakob Tholander is an associate professor at Stocholm University Sweden. He is a researcher in Human Computer Interaction and has studied various aspects of interaction design and body-centric computing ranging from tangible technologies, to sports and recreation, and to musical performance.

Jakobth@dsv.su.se

Anna Lisa Martin-Niedecken is a Senior Researcher at the Zurich University of the Arts, Subject Area Game Design. With her background in sports science her R&D work mainly focuses on movement-based games. She is particularly interested in how technology shapes gameplay/bodily experiences in the individual and social play context.

anna.martin@zhdk.ch

Elena Márquez Segura is a postdoctoral researcher in the Social Emotional Technology Lab at the University of California, Santa Cruz. Her research and design focus on movement-based co-located social interaction. Recently, Elena has been working in the domain of social wearables and social VR. Elena also specializes in novel embodied ideation methods for the design of rich physical and social experiences in collocated settings. She has used her methods to facilitate and lead ideation activities in various domains, including physical rehabilitation, interactive performances, movement-based games and play experiences, and future envisioning workshops.

elena.marquez@ucsc.edu

Elise van den Hoven is full professor in the Faculty of Engineering and IT at UTS, associate professor in the Department of Industrial Design at Eindhoven University of Technology (TU/e), and has two honorary appointments. She leads the Materialising Memories research program, using design research to support remembering activities.

elise.vandenhoven@uts.edu.au

Nicholas Graham is a professor at the School of Computing, Queen's University, where he performs research in game design and development. His group focuses on exercise video games (exergames) for children with disabilities such as cerebral palsy.

nicholas.graham@queensu.ca

Kristina Höök is a professor in interaction design at the Royal Institute of Technology (KTH). Her research focuses on soma design, affective interaction, bodily engagement, and aesthetics.

khook@kth.se

Corina Sas is full professor in HCI and Digital Health at Lancaster University, UK. She has expertise in technologies for wellbeing and health, and currently leads AffecTech, a Marie Curie innovative training network on personal technologies for affective heath.

corina@comp.lancs.ac.uk

Insights

- Presents key components of a future research agenda around body-centric computing based on a Dagstuhl seminar compiled by a group of experts.

- We need to consider how to connect embodied interaction design to both *in-bodied* design (how much do we need to know about how we work as complex systems under the skin) and *circum-bodied* design (how bodies are mediated both inside and outside via the microbiome); how that physiological mediation puts under erasure what we construe as inside/outside our bodies.

- We need to negotiate the balance between *body*-driven and *technology*-driven development (i.e., understand the needs of the human body and mind, the constraints that certain technologies place on the human body, and how they influence the systems that the HCI research community creates).

- We need to further develop our conceptual apparatus for designing and theorising body centric technology, allowing diverse perspectives to communicate about the challenges we face, especially concerning how to get design approaches, technology and perspectives on the body (*ranging from inbody, onbody, around the body, and between bodies)* to productively meet.

References

1. Höök, K., Jonsson, M., Ståhl, A. and Mercurio, J., Somaesthetic Appreciation Design. *CHI'16, 3131-3142*.
2. Martin-Niedecken, A.L. and Götz, U., Go with the Dual Flow: Evaluating the Psychophysiological Adaptive Fitness Game Environment "Plunder Planet". *International Conference on Serious Games*, (2017), Springer, 32-43.
3. Mueller, F. and Young, D., Five Lenses for Designing Exertion Experiences. CHI'*17*, 2473-2487.
4. Patibanda, R., Mueller, F.F., Leskovsek, M. and Duckworth, J., Life Tree: Understanding the Design of Breathing Exercise Games. *CHI PLAY*'17, 19-31.
5. Svanaes, D. and Solheim, M., Wag Your Tail and Flap Your Ears: The Kinesthetic User Experience of Extending Your Body. *CHI'16 Extended Abstracts*, 3778-3779.