Reconciling Technology-Driven and Experiential Approaches for Movement-Based Design

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Réconcilier les approches technologiques et expérientielles pour le design basé sur le mouvement

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ABSTRACT

Human movement is rich and complex and has been studied from two seemingly opposing design approaches: technology-driven design which seeks to continuously improve movement and gesture creation and recognition for both the user and the system; and experiential design which explores nuances of aesthetic human movement, cultivates body awareness, and develops methods for movement in embodied design. We compare and contrast these approaches with respect to their intended users and contexts, focus of the movement, and respective stages of the technology design process. We conclude with a discussion of opportunities for future research that takes both perspectives into account.

CCS CONCEPTS

• **Human-centered computing** → **Gestural input**; **Empirical studies in HCI**.

KEYWORDS

Movement-based Interaction, Gesture-based Interaction, Experiential Body

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RÉSUMÉ

Le mouvement humain est riche et complexe et a été étudié à partir de deux approches de conception apparemment opposées : technology-driven design qui cherche à améliorer continuellement la création et la reconnaissance des mouvements et des gestes, tant pour l'utilisateur que pour le système ; et experiential design qui explore les nuances de l'esthétique des mouvements humains, élabore une conscience du corps, et développe des méthodes de mouvement dans la conception incarnée. Nous comparons et opposons ces approches en fonction des utilisateurs et des contextes visés, du point focal du mouvement, et respectivement des étapes du processus de conception d'une technologique. Nous concluons par une discussion sur les possibilités de recherche future qui tiennent compte de ces deux perspectives.

MOTS-CLÉS

Interaction basée sur le mouvement, interaction gestuelle, corps expérientiel

1 INTRODUCTION

Computing continues to move away from the desktop and workplace context, having a more and more ubiquitous presence. Ever since the mobile phone entered the market in the 1980's[1], mobile computing has grown, to the point that in 2011, the number of mobile phones overtook that of landlines in the United Kingdom[2]. In 2010, Steve Ballmer noted the transition from mouse-and-keyboard-based technologies to more "natural" interfaces based on "touch, speech, gestures, handwriting, and vision"[3]. That same year, Microsoft released the Kinect which allowed for movement-based interaction within the home. A year later, Fitbit released an impressive update for its wearable activity tracker[4]. Additionally, the following fives years saw more advancement in body tracking devices with

[1]https://www.tigermobiles.com/evolution/
[2]https://www.telegraph.co.uk/technology/mobile-phones/8581624/Mobile-phone-calls-overtake-landline-calls-for-first-time.html
[3]https://www.huffpost.com/entry/ces-2010-a-transforming-t_b_416598
[4]https://www.wareable.com/fitbit/story-of-fitbit-7936

the Apple Watch[5] and movement tracking and generation with discoveries in deep learning[6]. Even though these technologies existed and had been studied previously within a lab setting, the user ability to purchase and bring home these technologies posed an opportunity and need for researchers, especially within Human-Computer Interaction (HCI), to develop and improve interaction.

At the same time, others like Bødker [6] observed the implications of the ubiquity of technology: the continuously blurring line between the workplace and the home, the broadening use context and applications, and the inclusion of other aspects of life such as culture and experience. Within body- and movement-based interaction, researchers like Höök and Mentis integrated and designed for the experiential body as it is defined in philosophies like phenomenology: "It (the body) is... the condition and context through which one is in the world" [22]. Some like Loke and Robertson trained in and integrated movement studies or body-based practices like the Feldenkrais method [16] and making strange [19] into their research. From repercussions of available body-based technologies, these communities of researchers approached interaction design outside of the task-filled workplace, placing importance on the experiential body and its movement within the greater social context.

We hypothesize that comparing these coincident yet dissimilar trends in HCI research will bring to light potential opportunities. Therefore, we define two terms for discussing works which hail from one of the trending approaches or the other: *technology-driven design* and *experiential design*. In *technology-driven design*, the overarching goal is to improve interaction with a specific piece of technology which exists in a specific context. In this case, researchers develop potential scenarios in which the technology could exist or if it is already on the market, draw from and test within the existing contexts for improvement. On the other hand, we define *experiential design* as encapsulating works which have the goal of exploring and integrating into design elements related to how the conscious body experiences, reacts to, and perceives the world around. In this case, researchers study how the body understands, feels, and senses the movement it is creating. If technology is explicitly present, it is present as a tool for design or used for uncovering and understanding nuances in movement.

To facilitate comparison, we define and employ the term *aspects* of interest of a design approach: the combination of design features and user study methodology that specifies the goals and choices of users, as well as the context and procedures. With this term, we present the following questions which framed our work: What aspects differ between these two approaches? What aspects of the approaches are similar? How does each approach and its aspects impact the results? How could we beneficially re-imagine the approaches to view design opportunity with novel outcomes?

We present a comparative essay of our two defined approaches in order to create and resolve a tension through their divergent nature. Therefore, we intend to compare these approaches in order to re-imagine alternative design practices rather than structure the literature around these two approaches. To do so, we further clarify technology-driven design and experiential design through some of the existing literature, mapping publications to their associated design approach. We follow by analyzing the set of works through their aspects. Then, we finish by discussing potential ways of re-imagining the two design approaches when partially integrated into each other.

[5]https://www.wareable.com/smartwatches/apple-watch-review

[6]https://adeshpande3.github.io/The-9-Deep-Learning-Papers-You-Need-To-Know-About.html

2 TECHNOLOGY-DRIVEN DESIGN

We define technology-driven design to include works whose goal of improving movement- and gesture-based interaction entails developing the best gesture for each command. For the system, this means a high likelihood of recognition. For the user, this means interacting using a gesture set that is easily discoverable, learnable, and memorable. Under this definition, we include works which either help a (non-technical) interaction designer or end user explore, create and/or learn a gesture set in the 2D or 3D space during early stage, mid stage, or prototyping phases. More specific goals include offering clearer communication between the system and user and understanding user behavior in gesture creation. For clarity's sake, we define a gesture as any movement generated by the user to control an interactive system. Since we categorize the following works in technology-driven design, we plan to see studies surrounding specific technologies examined within specific constructed or existing scenarios.

We include references based on their publication date and breadth across the approaches we defined, as well as across the different chosen aspects of each approach. Publication dates range the mid-2000s to the mid-2010s, concurrent with the aforementioned trends, when many ubiquitous-computing technologies hit the market and Bødker's Third Wave paper [6] appeared. Chosen references also present aspects that permit interesting comparison and cover contrasting goals, limitations, and contributions (methodological vs. technological). We refine the group of references by selecting those with either the greatest impact (measured via citations) or that offered insightful critiques of those papers. For example, we include Wobbrock's most cited work on user-defined gestures for tabletop surfaces [33] which is the first implemented gesture elicitation study ever run [30]. We also include work by Donovan and Brereton [10] which we label as technology-driven design but which happens early enough in the design phase to not study a completed system. Additionally, we do not filter references based on a particular type of movement or gesture, but focus on having a range in methodology. We note that we do not intend to do an exhaustive review of the literature, but rather choose references based on these fairly tight criteria.

2.1 Testing a Developed Prototype

Here, we present a few examples of prototyped systems designed for supporting the user in gesture design. These systems can, for example, reveal the available, unused space to the user midgesture or present tracking and system recognition information to the user for reflection. We break this section down into two parts: support for designers in gesture design and support for end-user gesture creation and execution through dynamic guides.

2.1.1 Supporting the Designer Design for the User. Ashbrook and Starner [3] proposed MAGIC, a system for gesture recognition, visualization, and comparison, to help users successfully design gestures with the system point of view; however, they found difficulty in presenting and visualizing information comprehensibly. MAGIC, or Multiple Action Gesture Interface Creation tool, offered support for: gesture creation and tracking by recording accelerometer and displacement data; gesture testing for recognizability against similar gestures meant to "trick" the system; and false positive checks against everyday movements found in the included Everyday Gesture Library database. MAGIC visualized data of gestures, test samples, gesture occurrences, etc., in tables and graphs or videos. For testing, the authors asked users (experienced UI designers) to create gestures with high levels of goodness (high levels of system recognizability) and low levels of gesture overlap with everyday movements. The team found that users took advantage of video playback to remember previously designed gestures and to discern which gestural features caused system misidentification, but barely took advantage of other data. Also, Ashbrook and Starner received mixed reviews related to feedback comprehensibility and resulting emotional responses (e.g. frustration from not understanding).

Kim and Nam [15] developed the EventHurdle, a software tool to help designers rapidly and iteratively prototype sensor-recognized gestures. EventHurdle, a system which recognizes and automatically codes movements, presented user-defined gestures on a 2D interaction workspace, allowed for gesture definition with visual markup language, and automatically generated related code snippets for quick prototyping. When placed in the hands of design students then professional designers, EventHurdle supported users in designing then testing gestures in recognition test mode as well as staying in the flow of design. Still, designers wished for the tool to include more radical idea exploration.

In these studies, researchers developed and tested systems meant to help gesture interaction designers against common design obstacles including difficult iterative visualization and retrospection, false positive testing, and time-consuming interaction prototyping (especially when not technically trained). Researchers therefore approached improving gesture-based interaction by simplifying, presenting, and in some cases, making interactive, system recognition information. Designers could then develop gestures around this information. In the next section, we describe projects in which researchers took a different approach: assisting and understanding end users (without interaction design experience) in gesture creation and/or completion.

2.1.2 *Let's See the End User's Approach: Dynamic Guides.*

Bau and Mackay [4] designed a dynamic guide called Octopocus that combined forms of feedforward and feedback to support users in learning and remembering mobile phone screen gestures. To clarify, dynamic guides present users with "continuously updated information" during gesture execution. In this implementation, the system presented the user with possible paths that correspond to recognized gestures. As the user continued the gesture, the less likely paths became thinner and thinner until they disappeared. When tested against a standard Help menu then a Hierarchical menu, users outperformed with Octopocus, resulting in better user learning, execution (thus easier system recognition), and remembering.

Delamare et al. [8] implemented OctoPocus3D meant to aid users with mid-air gesture execution. Similarly to the OctoPocus system for a mobile device, Delamare et al. presented potential gesture paths as pipes in a 3D space with diminishing radii. During testing, the user viewed the path visualization and their Kinect-tracked gesture on a desktop screen in front of them. When comparing OctoPocus3D with other feedback and feedforward mechanisms from the literature, Delemare et al. found an initial but not continued increase in the system recognition rate and a lack of influence of visualization scene stability on recognition rate.

Lastly, Malloch et al. [20] compared feedforward dynamic guides, called fieldward and pathward, for supporting user creation of memorable, machine-recognizable touchscreen gestures. Pathward, whose implementation draws inspiration from Octopocus [4], revealed the negative space and proposed next steps for a gesture in the form of line or arc segments. In the fieldward guide, Malloch et al. depicted the screen space as a heat map, blue representing the negative space and red representing a gestural next step that would form an existing gesture. The team found that most users placed importance on memorability, creating gestures they could remember then adding a "tail" for system recognizability reasons. The fieldward guide best encouraged this approach, resulting in longer gestures that users did not seem to mind.

In these works, research teams took the approach of improving gesture learning, correct execution, and memorability through system support for the (untrained) end user. Again, the teams presented "simplified" system gesture recognition information and, in this case, transformed it to guide the end user in gesture execution. Additionally, not only did teams focus on the success of the system in aiding the user but also inspected user strategy for insights into human behavior.

2.2 Demonstrating a Methodology

The second type of research that we categorize as technology-driven design encapsulates works which present methods for supporting users in creating gesture commands without system recognition. These include methods for utilizing reinforcement to encourage exploration of a user-sensor movement space and for uncovering and presenting a taxonomy of gesture vocabularies from future end users. We also divide this section into two parts: methods for movement and gesture exploration and forms of gesture elicitation.

2.2.1 *Early Stage Exploration.*

Williamson and Murray-Smith [31] developed a systematic technique for mapping out the range of possible movements for any sensor placed anywhere on the body. They employed reinforcement through audio feedback for user exploration of movement novelty within a joint user-sensor space. The authors broke gestures up into micromovements, and defined a codebook of distinct motions (composed of micromovements) in order to track the novelty of each movement. For reinforcement, the team chose to use audio decay based on the originality of the movement performed, ranging from pleasing to not so pleasing. Williamson and Murray-Smith tested their methodology with untrained users wearing an inertial sensor mounted on the elbow or wrist, finding similarly sized user-sensor spaces for both.

Donovan and Brereton [10] developed the Meaning in Movement game to explore actions and gesture in early-stage design in order to better understand and design an appropriate future system for particularly skilled users in structured contexts. Dental professionals are examples of users with pre-developed, expert-level fine manual skills who, due to health codes, work in a fairly extreme setting. To approach examining relevant gestures, the researchers developed Meaning in Movement: a game led by a facilitator in which users develop gestures from three user-proposed words related to their work. Though initially the researchers hoped for as minimal facilitator involvement as possible, the approach and directions given proved too general for the task. Therefore, the facilitator aided in leading the discussion to understand the three words, proposed acting out scenarios in the effort to transform words and sentiments into movements, and reminded users of the goal and requirements of the game. After, the team better understood the presence of the facilitator, who in the future, would participate at the same level as the users. Note: We chose to include this work for comparison since we label it as technology-driven design (due to the influence of the gesture command system final goal), even though it tackled such early design that a specific technological system was not yet involved.

In these works, researchers proposed methods for early-stage gesture exploration with potential end users. Through word-inspired games and reinforcement, ends users expressed their work experience through gesture or twisted their wrist to hear pleasing sounds. For the researchers, these methodologies helped with uncovering possible movements either for the joint user-sensor system or within specific scenarios motivated by future system development. In the next section, we present gesture elicitation studies, during which users define gestures for potential systems themselves.

2.2.2 Gesture Elicitation. Wobbrock et al. [33] studied how users invent tabletop gestures. The group experimented with the guessability study method [32] "that presents the effects of gestures to participants and elicits the causes meant to invoke them." During the study, the system presented the effects of 27 commands, and asked the user to create both one- and two-hand gestures for each while thinking-aloud. The researchers found that the gesture database created by members of the team only covered around 60% of the user-defined gestures. Additionally, the authors found influence of the desktop paradigm, presented for example by the fact that 72% of the user-defined gestures were mouse-like, as if a user's single-touch movement translated to a mouse click. Lastly, around 43% of the gestures were labelled as physical gestures, those that employed or assumed the presence of physics-based concepts from the real world. Lastly, they created a taxonomy of user-defined surface gestures and related agreement scores. Tsandilas [29] offered a detailed critique of the above gesture elicitation methodology and called into question the entire methodology, which does not account for agreement that occurs by chance.

Ruiz et al. [25] made use of the same guessability method to discover user-defined motion gestures with mobile devices. Ruiz et al. studied motion gestures which occur when users translate or rotate the mobile device. Ruiz et al. asked users to design then perform 19 action- or navigation-based tasks in which either the user acted on the phone as a whole or a specific application. The gestures proposed encompassed multiple themes, two of which we note. First, many of the gestures resembled those executed when using today's mobile devices. For example, a large majority of participants (17/20) picked up and placed the phone on the ear to complete the 'Answer Call' command. Secondly, the authors found that some gestures reflected interaction with old-school technology like an old telephone and an Etch-a-Sketch.

Connell et al. [7] used the Wizard-of-Oz approach within the guessability study method to explore full-body gesture elicitation with children. We explore three of the five major themes that emerged from the videos and subsequent transcriptions gathered. Firstly, the authors found a relationship between previous technology use, gestures defined, and overall gesture consensus. Secondly, the authors found potential support for individual preference and age impact on the gestures developed. Lastly, their results showed the possible impact of contextual cues on gestures performed as well.

In each case, researchers implemented a guessability method to draw out gestures from adult and child users. Although they identified gestures by visually inspecting the video, rather than via system recognition, the technology defined and structured potential gestural inputs. Existing technological interactions also heavily influenced which gestures were identified. Overall, this approach aimed to unveil user behavior with existing technological devices, with the goal of improving design for gesture-based interaction.

2.3 Summary

Table 1 presents ten examples of technology-driven design research, including the target users, study context, intended design phase, e.g., when the support system or the methodology is used, and the focus of the movement, e.g., measure of movement the sensor captures, like position, speed, or visual shape. Bold examples are tested prototypes while non-bold examples are developed methodologies.

Table 2 identifies the overall goals of each study in Table 1. These studies target end users who work outside of computer science or design, and often take place in computer science (CS) laboratories, rather than real-world environments. These systems focus on two different phases of the design process: some support early-phase design, such as user-sensor motion space exploration; whereas others support users and designers in mid- or late-phase design activities, such as when creating gestures, iterating ideas or testing the design.

We highlight three relationships between pairs of aspects:

Focus of Movement and Technology: Movement possibilities by the user may be constrained by the system, the device on which it is implemented, and the type of gesture being captured. For example, since Fieldward and Pathward are implemented on a mobile device, user-invented gestures remained x-y line segments possible on a fifteen cm by seven cm flat surface. The technology also defined the body part in motion. For example, in *Rewarding the Original*, users explored movement with their wrists and arms while keeping their legs still while wearing the inertial sensor on their wrist or elbow. Lastly, the learned industry standards related to a specific piece of technology, like what Wobbrock et al. [33] termed the "desktop paradigm", influenced the users in defining gestures as seen through the high percentage of interaction imitation.

Target Users and Goal: We also find a difference between the study participants and the study audience. As noted, (untrained) end users were the participants in most of the studies. The research goals, on the other hand, generally focused on aiding designers in developing improved interaction and more "intuitive" gestures.

System	*Target Users*	*Study Context*	*Design Phase*	*Focus of Movement*
MAGIC [3]	Designers	CS Lab	Mid-stage	Mid-Air Acceleration
EventHurdle [15]	Designers	CS Classroom	Mid-stage	x-y Displacement & Mid-Air Visual Shapes
OctoPocus 2D [4]	End Users	CS Lab	Prototyping	x-y Displacement
OctoPocus3D [8]	End Users	CS Lab	Prototyping	x-y-z Displacement
Fieldward and Pathward [20]	End Users	CS Lab	Prototyping	x-y Displacement
Rewarding the Original [31]	End Users	CS Lab	Early	Mid-Air Acceleration & Rotation
Meaning in Movement [10]	End Users	in-situ	Early	Visual Shapes
Gestures for Surface Computing [33]	End Users	CS Lab	Early/Mid-stage	x-y Displacement
Motion Gestures for Mobile Interaction [25]	End Users	CS Lab	Early/Mid-stage	Mid-Air Acceleration
Elicitation, Child-defined Gestures [7]	End Users	in-situ	Early/Mid-stage	Visual Shapes

Table 1: Examples of Technology-Driven Design Research (CS: computer science)

Study Context and Goal: Finally, we note the interaction between the in-the-lab study contexts and the solution-driven study goals. Most researchers working with technology-driven design completed studies in a CS lab or classroom setting. Teams completed studies outside of a lab setting for specific target user groups including dental professionals and children. The study goals addressed explicit problems like the difficulty of "testing gestures in everyday life" or proposed clear solutions like a "general technique for establishing a set of motions suitable for use with sensor systems".

Through analysis, we first called attention to aspects of works we've labeled as technology-driven design, like a inclination toward CS lab study contexts and in the approaches taken (through observing interaction with a designed a prototype or applying a described methodology) for different design phases. After, we called attention to some cross-aspect observations including the link between the technology used and the focus of movement, the target users and the greater audience and goal of the paper, and the study context and goal of the study. These observations will be further discussed in relation to the experiential design analysis in the Discussion section. Additionally, we stress that our conclusions relate to the scope of this paper, as tendencies among the chosen aspects of chosen references which we use to describe technology-driven design, and not the literature as a whole.

We defined technology-driven design through example works which focus on improving gesture-based interaction through systems for supporting designer and user gesture creation/learning or through methodologies for early gesture exploration or elicitation. These works represented successful approaches for designing and testing gesture command interactions shaped by the constraints of a specific system and its purpose in a specific context. Limitations of this approach included a remaining difficulty in human-computer communication and finding novelty in gesture creation when interacting with known technologies.

3 EXPERIENTIAL DESIGN

We define experiential design to include works with approaches that start from the conscious body and its related perception and sensation during movement and interaction. Instead of using movement and gesture as recognizable command inputs, we include works which use technology as materiel for exploring inner sensation, to investigate movement perception and understanding among different populations, or as a resource for interaction and play, reflection, and discussion in embodied design. Our definition also

Name	*Goal*
MAGIC	Address a) "Designers are not generally domain experts in gesture" b) "Testing gestures in everyday life can be very difficult"
EventHurdle	Address: "Relating users' input from gesture-based sensor values requires a great deal of effort on the designer's part and disturbs their reflective and creative thinking"
OctoPocus 2D	"Helping users to learn, execute and remember new gesture sets"
OctoPocus3D	Address: Users not knowing "(1) What commands are available and (2) how to trigger them"
Fieldward and Pathward	"Help developers design novel gesture vocabularies support users as they design custom gestures for mobile applications"
Meaning in Movement	"Designing future interactive systems which are more appropriate to the types of skillful actions and richly structured environments"
Rewarding the Original	"General technique for establishing a set of motions suitable for use with sensor systems, by drawing performable and measurable motions directly from users"
Gestures for Surface Computing	"Help designers create better gesture sets informed by user behavior"
Motion Gestures for Mobile Interaction	For the designers: "Allow the creation of a more natural set of user gestures" For smartphone creators: "Guidance in the design of sensors"
Elicitation, Child-defined Gestures	"Explores the applicability of using the elicitation study methodology to examine child-defined gestures for whole-body interaction"

Table 2: Technology-Driven Design Example Goals

encompasses works which focus on developing methodologies for interaction design with and for the felt experience of the conscious body, for which corresponding technology can then be developed.

We note that we chose these references in a similar fashion to those which populate technology-drive design: based on publication date and overall breadth of the defined design approach. As stated, these works date from the mid-2000s to the mid-2010s and either have a great impact or put main methodologies into question.

3.1 Testing a Developed System

We classify works which contribute technological prototypes and related study results as one part of experiential design. In these examples, system designers study the interaction in an artistic context such as an interactive dance performance or exhibition, which facilitates movement exploration and contemplation. Additionally, due to the artistic nature of the setup, users range in level of exposure and curiosity to similar movement-based works, a majority being those with a base interest in the body and its sensations. Design of these systems could involve integration of existing tools or methodologies from body-based practices.

For example, Loke et al. [16] presented their system which successfully used "movement, touch, balance and proprioception as input modalities" and focused on somatic bodywork framed by the Feldenkrais methodology. The team of researchers, artists, designers, and Feldenkrais practitioners staged an event entitled the *Sensorium Gymnasium* which consisted of six experimental art pieces aimed "to translate the subtle and profound experiences of our own somatic experiments into aesthetic experiences for others." One of the pieces, Surging Verticality, consisted of a Wii fit, audio Feldenkrais recordings with headphones, and a stretchy large piece of fabric attached to the participant's heels. The pressure sensors in the Wii fit received information about the applied force from the user which, using Max/MSP[7], was translated into generated sound. Surging Verticality presented each visitor with the opportunity to probe into her sense of balance, weight change, and the notion of her own body. From analyzed audience comments, Loke et al. described audience member questioning, acquired awareness, and imagination related to balance and engagement plus the ability to experiment in the open studio atmosphere and through the Feldenkrais somatic method. Additionally, they noted that not all audience members responded positively as some felt more anxious and unbalanced during the experience. However, overall, the experience allowed for audience reflection.

Another example, entitled *Seeing Movement Qualities* [23], investigated everyday user ability to visualize, understand, and also perform movement qualities through an interactive dance performance. Mentis and Johansson created an artistic installation in which users controlled professional dancer performance and music played through movements performed in front of a Microsoft Kinect. Mentis and Johansson along with a Laban Movement Analysis (LMA) expert defined Kinect-detectable movement classes which corresponded with LMA's Effort qualities of Weight, Time, Space, and Flow[8]. The team recorded with the Kinect and video camera all user interactions as well as conducted post-event interviews, and compared qualities labeled for each 15 second interaction by the LMA expert, the system, and the users themselves. Mentis and Johansson found a difference in movement quality recognition, visualization, and classification between the LMA expert and the users (only 66% agreement). Additionally, they found that in such an open context (researchers did not give any system or performance explanation), the majority of users took other strategies outside of movement qualities when approaching the system, if they felt comfortable approaching at all. Lastly, Mentis and Johansson described the two scenarios in which they thought interaction through movement qualities would be useful: for user control of the system with explicit explanation (like *A Light Touch* by Alaoui et al. [1]) or to support user self-reflection.

In these works, researchers developed systems either to offer users the opportunity to explore nuances in their movement or to examine user and expert understanding of movement qualities. The researchers approached movement-based interaction through studying the potential for technological tools to uncover new movement sensation or understanding. The technology acted as an artifact for exploration and questioning for both the users and researchers.

3.2 Presenting a Methodology

Within experiential design, we also include works which present movement-based interaction designers with different methodologies. These methodologies can encompass one or multiple phases in the design process, changing shape based on the objective of the phase. We also include works which offer movement-based interaction designers with general strategies or guiding principles to be added to the designer's tool belt.

3.2.1 Comprehensive Methodology. Lian Loke and Toni Robertson [19] emphasized the first-person, felt experience within human-centered design when developing *Moving and Making Strange*. Artists use the method of making strange for creation, performance, and design to uncover movement possibilities by "unsettling or disrupting habitual perceptions and taken-for-granted conceptions of the moving body" [18]. Loke and Robertson combined making strange with results from multiple ethnographic studies focused on the act of falling and the choreographic practices of dance makers to generate Moving and Making Strange. The researchers proposed a "toolkit" for working with three main perspectives (the mover or the first-person perspective, the observer, and the machine) and perspective-corresponding movement-based activities to support the exploration and testing of design concepts. Loke and Robertson stated that there was a need for a "methodological shift in perspectives for designers such that one of their fundamental activities is cultivating the bodily awareness of the forms, processes, and qualities of movement being considered for design." [17].

Segura et al. [21] worked to "translate the abstract theory of embodied interaction into design practice..." which culminated into the methodology *embodied sketching*. The authors defined embodied sketching as "a characterization of design practices... that foregrounds the somaesthetic experience for the exploration of, and design for particularly interesting physical experiences." Through embodied sketching, the researchers intended to place importance

[7]https://cycling74.com/products/max
[8]http://www.laban-analyses.org/laban_analysis_reviews/laban_analysis_notation/overview/summary.htm

on ideation instead of evaluation, incorporate the felt experience earlier than usual when completing movement-based design, and incite creativity through play. They introduced multiple implementations of embodied sketching through the following scenarios: 1) bodystorming [26], a method during which designers use enactment for situated prototyping; 2) participatory embodied sketching, in which potential users manipulate an existing prototype and facilitators and surprisingly the users themselves adjust the socio-spatial configuration in order to encourage interaction creation; and 3) designer sensitization, in order for a designer to question and reflect on the first-person perspective and felt experience of a design. In the end, the researchers uncovered the strength in applying different implementations of embodied sketching for different moments, stakeholders, and degrees of establishment of the prototype or idea(s) within the design process.

In these works, researchers presented comprehensive methodologies to include the first-person perspective, felt experience and the somaesthetic experience in a variety of design activities. These teams therefore approached movement-based design through the development of methodologies as guidance for others designers. In the next section, we present works in which either through compiling design examples or speaking with experts in the field (including expert self-reflection), researchers delivered findings as tools for movement-based interaction.

3.2.2 Tool Belt of Strategies and Guiding Principles. Some teams utilized Research through Design [34], presenting design exemplars and lessons learned for other designers. For example, in *Move to get Moved*, Hummels et al. [14] presented their exploration of the notion 'interaction creates meaning' through interactive systems or methodologies like the Design Movement Approach and the Choreography of Interaction (in which "design is focused on creating activities and movements"). These projects and the resulting lessons learned culminated into 7 guiding principles for movement-based interaction including the richness over the tangibility in interaction and the need to design through moving and interaction.

Another examples is Höök et al.'s [13] work unpacking and explaining the strong first-person perspective through: soma-based design exemplars; methodologies like disrupting the habitual and autobiographical design; and theoretical underpinnings like Merleau-Ponty's [24] phenomenology of the body and definition of the first-person perspective, Dewey's [9] aesthetic experience, and Shusterman's [27] somaesthetics. With this ideological framing, Höök et al. engaged in a conference workshop, interacting with some participants' design exemplars, and discussing approaches for attending to the designer's bodily self while working with design materials. The patterns recognized from the spectrum of exemplars, which is presented to readers as an annotated portfolio [11], and the selection of author-employed, soma-based design methodologies, aligned with the importance of first-person perspective attendance and awareness development.

Others employed empirical methods like autoethnography and interview analysis to uncover design implications. Höök [12] dug deeper into designing for the felt experience of the body through her autoethnographic study of horseback riding. Seven themes emerged including: the delicacy of signals sent between two independent agents; the continuous transition between viewing the body externally and the sensations experienced internally, and how understanding that relationship can lead to improved expression of experienced moments; and the importance of rhythm and balance as aesthetic experiences. She transformed these themes into clearly applicable design implications such as the need to incorporate rhythm into aesthetic experience design and the emphasis on silent, sensitive signals that lead to a partnership of mutual understanding.

Through interviews with prominent researchers in embodied design, Alaoui et al. [2] uncovered methodologies and challenges of movement (self)observation, an irreplaceable tool for deciphering and translating felt experiences for easier adoption. The authors brought to light and formulated the following techniques: attunement (as preparation for observation), attention (to own experience or to patterns among others and their surroundings), and kinesthetic empathy (in order to feel with other body/ies). They reported on the frustrations of fluctuating between the "inner embodied state" and the "outer design mode" and expressing felt experiences in textual language not only for self-understanding but also while communicating with other stakeholders.

Researchers discussed, reflected on, and interacted with each other and their projects in order to uncover overarching themes and concrete tools for movement-based interaction design. As in the previous section, these researchers approached improving movement-based design with guidance for other designers and researchers. However, in this case, the tools came in the form of guiding principles for the design tool belt.

3.3 Summary

Table 3 presents eight examples of experiential design research, including the target users, study context, intended design phase, and focus of movement. Bold examples are tested prototypes while non-bold examples are developed methodologies.

Table 4 identifies the overall goals of each study in Table 3. As before, we see a relationship between the approach, e.g., testing a developed system or presenting a new methodology, and the target user group, i.e. end users or designers. These studies involve diverse settings, with a special emphasis on artistic contexts. Here, the foci of movement often encapsulates subtle aspects of movement, such as sensation and perception, which as seen, technology-driven design tends not to address.

We highlight three relationships between pairs of aspects:

Focus of Movement and Technology: We see a link between a study's focus of movement and the presence of the technology. The only example in which researchers included clear movement definition was "Seeing Movement Qualities," in which researchers studied end user understanding through system interaction. Otherwise, the focus of movement included elements of movement not specifically apparent to an outside observer or directly recognizable by a system like the felt experience and sensation perception. In these studies as well, if hardware or software technologies were present, researchers used them as "design resources" [21]. Additionally, the possible movement and body parts used were boundless. We concur the aspects and diversity of types of movement explored relate to the technology's presence and use during a study.

System	*Target Users*	*Study Context*	*Design Phase*	*Focus of Movement*
Re-sensitising the Body [16]	End Users	Artistic Exhibition	Prototyping	Nuances of Movement & Sensation
Seeing Movement Qualities [23]	End Users	Interactive Performance	Prototyping	LMA's Effort qualities
Moving & Making Strange [19]	Designers	Immersive Space	Structuring Exploratory Activities	Felt Experience
Embodied Sketching [21]	Both	in-situ	Structuring Exploratory Activities	Felt Experience
Move to get Moved [14]	Designers	Diverse	Structuring Exploratory Activities	Interaction Perception
Embracing First-Person Perspective [13]	Designers	Workshop	Throughout	Felt Experience
Transferring Qualities [12]	Designers	in-situ	Throughout	Felt Experience
Strategies for Embodied Design [2]	Designers	Workshop	Throughout	Felt Experience

Table 3: Examples of Experiential Design Research

Target Users and Goal: Additionally, we notice the personal inclusion that the goals subtly describe even when the target users are end users. To start, the goals include terms such as "the central role of the body" and "bodily experiences," exhibiting a encompassment of all possible users since as humans, we each have a body through which we experience the world. Additionally, in studies for end users, the goals represent either translating experiences for others to feel or studying a concept like movement perception but within the plural context: the user, expert, and researcher movement perception of themselves and others. In studies for designers, the inclusion is also present in supporting other designers to become "expert in movement-based interaction" or in questioning "bodily experiences we may aim to design for."

Study Context and Goal: Lastly, we note a tendency between the contexts (outside of the lab) and exploratory goals. Study contexts were either artistic, interactive, or realistic (in-situ). The goals invoked ideas of questioning through "investigat(ing) the value and challenges" and "shed(ding) light on... possible bodily experiences".

During analysis, we brought attention to aspects of our labeled experiential design works including the increased presence of subtle aspects of movement representing the foci of movement and the link between the approaches taken (through studying interaction with a technological probe or developing a methodology) and the target users. Additionally, we again pointed out cross-aspect observations including the correlation between the focus of movement and the technology use, the target users and the audience of the goal, and the study goals and contexts. These observations will be further examined in relation to technology-driven design in the following section. Again, we stress that our conclusions relate to the scope of this paper, as we consider tendencies among the chosen aspects of chosen references to describe experiential design, not the literature as a whole.

We defined experiential design through selected works which place priority on listening, perceiving, and communicating the felt experience of the conscious body in order to a) design systems for supporting or uncovering nuances in movement exploration or understanding; or b) integrate the felt experience into movement-based interaction design. These works successfully translated sensual experiences into technology-infused exhibitions and design guidelines. Limitations included continued difficulty in a) communicating and sharing felt experiences and b) system and method approachability for non-experienced, hesitant users.

4 DISCUSSION

Study aspects, such as users and context, encourage research projects to develop certain atmospheres, values, and relationships between the user and the researcher. For example, our analysis of technology-driven design identified that: a) the positioning of technology constrains the possible movement so that it can be detectable, therefore, influencing the focus of movement for a study; b) in technology-driven design, though the audience of a work is

Name	*Goal*
Re-sensitising the Body	"To translate the subtle and profound experiences of our own somatic experiments into aesthetic experiences for others"
Seeing Movement Qualities	"To situate the perception of movement qualities – both in terms of perceiving one's own movement qualities as well as perceiving the qualities in another's movements"
Moving & Making Strange	"An approach to movement-based interaction design that recognizes the central role of the body and movement in lived cognition"
Embodied Sketching	"A way of practicing design that involves understanding and designing for bodily experiences early in the design process"
Move to get Moved	"Illustrate... which kind of methods, tools, knowledge and skills can help designers become and act as experts in movement-based interaction"
Transferring Qualities	"To shed some light on... What are the possible bodily experiences we may aim to design for, and how can we characterise them?"
Strategies for Embodied Design	"Investigate the value and challenges of observing movement experience in embodied design"
Embracing the First-Person Perspective	"Unpack one of the design sensitivities unique to our practice: a strong first person perspective"

Table 4: Experiential Design Example Goals

System	*Target Users*	*Study Context*	*Focus of Movement*	*Goal*
TDD Prototypes	Both	CS Lab	x-y(-z) Tracked Changes	Support users & designers in gesture design or learning
TDD Methods	End Users	CS Lab/In-situ	x-y(-z) (Non)Tracked Changes	Explore (all) possible mov'ts & uncover user gesture behavior
ED Prototypes	End Users	Exhibition	Sensation & Qualities	Translate or understand movement sensation & qualities
ED Methods	Designers	In-situ & Workshops	Felt Experience	Support design for the experiential body

Table 5: Overview of Analysis: (TDD: Technology-Driven Design, ED: Experiential Design)

system designers and researchers, the target users tend to be non-technical end users and interaction designers; and c) the positioning of the technology leads to studies conducted in computer science research lab settings.

These examples suggest that we create study scenarios in which researchers remain distant and observe untrained users as they develop the movements that they would like, given the constraints implicitly produced by the device and its positioning. We thus find outcomes with respect to gesture vocabularies to be unsurprising and heavily influenced by industry norms.

Similarly, from our experiential design analysis with its different positioning of technology and the related a) exploratory context with b) researchers and potential users, and c) an unstructured openness toward movement, we uncover difficulties in system approachability due to a lack of structure and in recognizing and translating perceived sensations into a shareable format.

We therefore would like to re-imagine the relationships and values within the two design approaches defined above by altering analyzed aspects and discussing potential outcomes.

4.1 Integrating the First and Second Person Perspective into Technology-Driven Design

As previously stated, technology-driven design results in a researcher role of outside observer, tracker, and analyzer of the set of users, meaning she takes the third-person perspective. On the other hand, experiential design incorporates more first- and second-person perspectives as researchers and users alike can observe and communicate perceived sensations. We could imagine integrating first- and second-person perspective into technology-driven design by including a movement exploration phase during gesture design or elicitation with a subsequent discussion of user inner sensations.

What impact would this integration have on a technology-driven design study? We hypothesize that the researcher would then take a more personal approach to observing the user, incorporating techniques such as attunement, attention, and kinaesthetic empathy. The researcher would also explore the user performed movements herself. The roles of user and researcher would then approach each other, meaning the study would have less of a performance-feel and act more as an exploration with play. We speculate then that designed gestures would expand past industrial standards. We imagine gesture innovation and discovery of more innate user behavior when placing importance on activities supporting the first- and second-person perspective in technology-driven design.

4.2 Integrating Structure for Movement Capturing into Experiential Design

As previously mentioned, in experiential design, the felt experience has a central role. The technology is positioned to support the user in this process as a design resource or material through which the user can experience novel sensations within an exploratory context such as a workshop or immersive space developed by or with the researcher. However, what if we want to capture and analyze movement from a workshop?

As seen in technology-driven design, we imagine the potential constraint if we explicitly include tracking technology like mobile phones or wearable sensor. A first-person perspective post-session with a Body Sheets [28] is another option for capturing movement data from a workshop. However, the nuance in personal reflection of sensation would hinder the possibilities of creating a sort of standardized translation for capturing. Therefore, we could imagine an outside viewer, like a video camera or an expert annotator, translating the movement from a session into a standardized language. We note that for LMA, for example, Bernardet et al. [5] found that inter-rater reliability ranged from weak to acceptable. However, a single LMA expert transcribing could give standardized interpretation and translation of movement from a movement exploration session that could be used to capture the movement. Finally, the inclusion of an outside expert viewer could change the trusting atmosphere and the user-researcher relationship of the experiential design study.

4.3 Methodological Impact and Limitations

We highlight the limitations of our design re-approaches since the overall movement- and gesture-based interaction context played a large role in their development. We defined both technology-driven design and experiential design in relation to a split within movement- and gesture-based design, displayed through events like the commercial explication of "Natural User Interfaces" and the integration and expanded discussion of somatic practices and phenomenology into HCI. As Bødker noted [6], with more ubiquity in technology comes a broadening of contexts; therefore, we paid high attention to the context and environment within each defined approach. We do realize, however, that research on movement- and gesture-based interaction with more ubiquitous technologies has been around for much longer. We therefore chose references that situated within our selected time range and which either presented or questioned the status quo being developed, especially methodologically. Because of our interest in understanding the implications of these trending yet divergent approaches, we specifically looked at contextual aspects of a system within the study ecosystem, e.g. greater goal of the authors, target users, study context, etc. These chosen aspects led to a discussion therefore related to resulting study atmosphere, values, and relationships. We could imagine very different design re-approaches if, for example, we chose to highlight the variety of definitions for gesture within the related timeline and context or if we followed the evolution of gestures in relation to developing technology. However, by framing this comparison through divergent trends which arise from reactions to particular movement technology development, we extract opportunity from opposition, contributing relevant, re-imagined design approaches and therefore participating in the advancement of movement-based interaction design.

5 CONCLUSION

Inspired by research trends beginning in the early 2000s, we define and compare two approaches to gesture- and movement-based interaction design: *technology-driven design*, which focuses on improving command-based interaction with a specific technology in a specific context, and *experiential design*, which focuses on integrating and uncovering the felt experience in interaction. We illustrate our definitions by categorizing selected related works, and analyzing each based on specific aspects of the study, including: study context, design phase, and focus of the movement. We present relationships between pairs of aspects, such as the link between the target users and the overall study goal, and compare them. We also discuss the atmosphere, values, and user-researcher relationships that result from configuring different elements from each design approach. We conclude with insights for re-imagining these approaches when elements of each are integrated into the other approach and the resulting impacts on study outcomes.

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