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Interaction designers' perceptions of using motion-based full-body features

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ABSTRACT

Movement-based full-body interactions are increasingly being used in the design of interactive spaces, computer-mediated environments, and virtual user experiences due to the development and availability of diverse sensing technologies. In this context, the role of interaction designers is to find systematic and predictable relationships between bodily actions and the corresponding responses from technology. Sensor-based interaction design relies on sensor data analysis and higher-level feature extraction to improve detection capabilities. However, understanding human movement to inform the design of motion-based interactions is not straightforward if the detection capabilities of interaction technologies are unknown. We aim at understanding the problems and opportunities that practitioners—regardless of their technical background—perceive in using different motion-based full-body features. To achieve this, we conducted four separate focus groups with experienced practitioners, with and without technical backgrounds. We used a framework for the analysis of focus group data in information systems research to identify content areas and draw conclusions. Our findings suggest that most interaction designers, regardless of their technical background, consider motion-based feature extraction to be challenging and time-consuming. However, participants acknowledge they might use *designer-interpretable* features as a potential tool to foster user behavior exploration. Understanding how practitioners link sensor-based interaction design with feature extraction technology is relevant to design computational tools and reduce the technical effort required from designers to characterize the user's movement.

1. Introduction

Novel interactive environments have emerged from the confluence of motion detection technology and sensor-based interaction design. The capture and processing of human signals from the whole body have become a common interest among human-computer interaction (HCI) researchers as body motion is considered a natural form of interaction with the physical world (Loke et al., 2007). Since bodily motion can act as a direct form of input to such systems, interaction design researchers have raised questions about its potential use and consequences in HCI (Rogers and Muller, 2006). Design challenges inherent in sensing systems have been of interest to interaction design researchers while looking for interfaces to actively respond to a wide variety of user behaviors (Eriksson et al., 2007; Loke et al., 2007). From a theoretical perspective, designers have explored the relationships between movement and corresponding user-centered interaction from different angles (Bellotti et al., 2002; Loke et al., 2007). As a result of this, conceptual frameworks grounded in cognitive and perceptual assumptions, like Michelis and Müller (2011), Benford et al. (2005), Daiber et al. (2011) are considered by interaction designers as human-computer communication strategies (Rogers and Muller, 2006). However, Interaction designers are constantly faced with an evolving range of technologies and usually face the common challenge of translating raw sensor data into a feature model representation suitable for its use in a creative context. To reduce the technical effort from designers to create new interaction models using the sensing capabilities that current technologies offer, it is important to understand the problems and opportunities that interaction designers perceive in using different motion-based full-body features. Therefore, this paper explores interaction designers' opinions about technical tools and motion-based features they have used, to understand how they link conceptual design frameworks with available sensing technology in their daily work.

This paper considers interaction design as defined by Preece et al. (2015): "it is about designing spaces for human communication and interaction." Some terms used to emphasize relevant aspects of what is being designed include user experiences, digital artifacts, interactive

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systems, and software prototypes. However, since interaction design is considered a multidisciplinary field with different approaches depending on the practitioner's professional orientation and goals (Fallman, 2003), we think it is crucial to clarify the perspective of this article. In particular, this paper focuses on designers interested in movement-based interaction who aim to design experiences that take advantage of the benefits of physicality to enhance the user experience, facilitate its appropriation, and introduce the body as a mediator of meaning-making (Hummels et al., 2007; Loke and Robertson, 2013). In line with the above, the present study values the crucial role of the body in knowledge construction in digital domains and argues consistency with cognitive science findings (Wilde et al., 2011).

As Gillies (2019) remarks, movement-based interaction design considers movement knowledge in embodied and representational forms, as both yield very different interaction design approaches. Embodied knowledge is considered by many (Gillies, 2019; Hummels et al., 2007; Loke and Robertson, 2013) tacit, implicit, closely related to embodied cognition, and a key aspect to understanding movement interaction. Embodied approaches to movement interaction design consider both the conceptualization of movement as a design material and the need for designers to develop bodily movement skills (Hummels et al., 2007) as key principles to work with the expressive meaning of the moving body (Loke and Robertson, 2013). In contrast, representational knowledge of movement interaction refers to explicit, symbolic, and well-established interaction mechanisms associated with a traditional interface (e.g., a graphical user interface composed of visual representations of the computational system and its many different representations of possible actions) (Gillies, 2019). Of particular interest in this context is the work by Márquez Segura et al. on first-person embodied design (Márquez Segura et al., 2016). Their study presents a design practice called Embodied Sketching, which considers movement knowledge as largely implicit (i.e., allowing designers to design in an embodied way through movement and reflection) but with elements that support the communication of representational movement knowledge with other designers. The above discussion frames our study in a particular two-fold view of movement-based interaction design: (1) understanding particularly designed movements through embodiment, and (2) communicating that knowledge to other people and the machine as the interaction gets implemented.

Technologies for full-body motion capture are classified as optical or non-optical systems (Zhu and Li, 2016). Each of these presents advantages and disadvantages regarding accuracy, robustness, latency, and complexity, as it is common in heterogeneous sensing technologies. Non-optical systems use inertial measurement units that embed an accelerometer, a gyroscope, and a magnetometer and can be bound to the body. Such systems are inexpensive and fast, although commercial products are perceived as weighty and intrusive (Leoncini et al., 2017). Optical systems use computer vision to capture, recognize, and track users and are classified as marker-based or markerless. Marker-based systems are well known for being precise and expensive, being its main drawback, the requirement of wearing a tight marker bodysuit that causes discomfort (Caserman et al., 2020). As most relevant for full-body interaction, markerless systems use images obtained from multiple cameras to capture human gestures without instrumenting the users (Sundaresan and Chellappa, 2005). Among all these, our research focuses on markerless systems, considering computer vision as the technology basis for feature extraction and motion analysis during the study. A markerless solution was chosen for three main reasons: (1) cameras can track users and report full-body information without special wearable add-ons or markers, (2) multiple cameras in a network allow real-time multiple-people tracking in big volumes and without occlusions by overlapping individual fields of view, and (3) as sensors, camera vision, and associated software become more available, designers and researchers are exploring richer ways of interacting (England, 2011). To narrow this scenario even further, the investigation makes emphasis on gestures and interactions where multiple people can move naturally and use their full-body to interact with the computer system, as it is common in interactive spaces design (Caserman et al., 2020). Thus, the concepts of multiple-users, motion-based, and full-body became premises that formed an extensive interaction design space to discuss the creation of diverse computer-mediated environments, immersive facilities, and interactive experiences (Caserman et al., 2020).

Eriksson et al. (2007) consider movement-based interaction as especially suited for interaction that takes place in a public or social context, providing interesting alternatives to traditional interaction techniques within social settings and public places. In their work, authors define the concept of *relation*, which represents the connection between a camera and the tracked features within the camera space. Moreover, a *relation* can be described by a set of properties that defines potential interaction inputs, the size of which depends on the algorithm used to analyze the camera output. The presence of a feature, the position of the feature in space, its state, identity, or information about uncertainty, are examples of properties associated with a *relation*. Finally, authors argue that interaction is triggered by mapping a different action to changes in a *relation's* property, pointing out that the number of relations and the number of properties associated with each *relation* greatly determines the interaction's complexity (Eriksson et al., 2007). However, the mere detection of certain tasks is not enough for interaction design and unfortunately, a purely technical approach focuses on the detection of people's activities, deferring any consideration of how the model is to be used. In our analysis of the above, we present the following two research questions that may explain the existing gap between motion-based interaction design and the technical development of interactive computer-vision systems. (1) Does the designer need to understand sensor data and its relation with interaction design possibilities to create novel interactive systems? (2) Does technical development of multiple-user motion-based interactions produce multiple sensor data, somehow decontextualized, from the user experience designers' point of view? To derive a conclusion from both questions and validate our argument, this paper explores practitioners' perceptions throughout the use of focus groups.

A focus group aims to bring out the perceptions, beliefs, and values of the participants. It is a well-known technique for obtaining research data through informal group discussions on a specific topic (Nili et al., 2017). The focus group focuses on the plurality and variety of responses from a group of people. It is a qualitative research technique whose objective is to obtain in-depth data on what the participants think and do, exploring the whys and hows of their opinions and actions (Hernández Salazar, 2008). It differs from other methods such as individual interviews and surveys, not only in the sense that the interactive and synchronous group discussion aspect of focus groups allows participants to discuss, agree, or dissent with each other's ideas, but also, in the researcher being there in the role of a facilitator for the discussion (Nili et al., 2017). Hence, it is not a question and answers session between the interviewer and the interviewees, but a collaborative discovery activity.

In an effort to evidence professional background diversity on interaction design practitioners, Wilde et al. (2011) acknowledge that designing for the body requires expertise in disciplines ranging from industrial and interaction design to engineering, computer systems design, and even arts and performance creation. In a similar form, Fallman (2003) describes the role of designers in HCI through three competing accounts, answering the question: what do designers really do in this field? The author named these accounts: conservative, pragmatic, and romantic, pointing out fields such as engineering, human science, and art, as their role models, respectively. To cover a wide range of experiences and related fields within this discipline, we gather interaction designers with diverse professional backgrounds under a focus group methodology (see Section 2.1). In particular, we designed the focus group with the following specific objectives: (1) to obtain information on the interaction design methodologies used by participants and their relationship to the use of sensing technology, (2) to understand what problems interaction designers face when trying to interpret raw data from sensors when using full-body motion-based technologies, and (3) to identify how designers relate the sensing capabilities of technology to interaction design possibilities.

The contributions of this work are summarized as follows: (1) We present results from focus groups to help other researchers and practitioners contextualize and understand how perceptions and barriers to movement-based interaction design are formed. (2) We report our findings pointing towards differences in perceptions according to the participant's backgrounds; for example, different assumptions on what design is, on the role of technology in design practice, or on the purpose of working with motion-based full-body features. (3) We convey our insight that the mapping of purely technical parameters to a set of *designer-interpretable* features constitutes an intelligible representation of the interaction design possibilities offered by sensing technology.

The paper is organized as follows. Section 2 presents the methodology we followed for carrying out the focus group, including the data collection and analysis strategies. Section 3 reveals perceptions of, and barriers to, using full-body motion-based features in a group of interaction designers. Section 4 discusses how the findings of the study are helpful for the problem statement of the research. And finally, Section 5 presents conclusions and suggests topics for further research.

2. Methodology

2.1. Participants

For the selection of the focus group participants, an appropriate profile with the following characteristics was defined. First, participants should have experience in interaction design from a practical perspective. We identified diverse working areas and focused our efforts on finding people with expertise in designing new interfaces, user experience for interactive systems, new media creation, or interactive digital arts. Second, participants must have prior knowledge in creating interactive full-body experiences based on movement or gestures. Potential participants were contacted with recruitment emails sent to interaction design professionals, all of them suggested by HCI research staff of the universities to which we are affiliated. All potential participants' profiles were first reviewed to ensure that they complied with the above criteria. Eight potential participants were excluded at this stage because they didn't meet these criteria, and five further participants declined for personal reasons. In total, 12 interaction designers between the ages of 25 and 50 years agreed to participate in the focus group. Participants were asked for their academic background to understand professional profiles and make the most general categorization possible. To this end, we used the work by Fallman (2003) as a reference. In his study about design-oriented HCI, Fallman (2003) addresses diverse roles and skill sets to conceptualize different views on design and presents three competing accounts. (1) A conservative account: "design is thought of as a scientific or engineering endeavor, borrowing methodology and terminology from the natural sciences, mathematics, and systems theory, drawing on a philosophical base in rationalism." (2) A pragmatic account: "rather than science or art, under the pragmatic account design takes the form of a hermeneutic process of interpretation and creation of meaning, where designers iteratively interpret the effects of their designs on the situation at hand." (3) A romantic account: "it nourishes the idea of 'creative geniuses,' a legacy of the Enlightenment. Designers are seen as creative individuals with unusual talents, who often have to fight opposition to defend their unique creativity and artistic freedom." As a result, three different categories (i.e., engineer, designer, and artist) in close correspondence with the conservative, pragmatic, and romantic accounts from Fallman (2003) were used to classify the study participants. Our sample included 4 engineers, 5 designers and 3 artists.

Information systems research literature advises on doing focus groups with a small number of people (Nili et al., 2017). Groups of more than 10-12 people are difficult to moderate, and participants have little time to intervene, generating more superficial speeches (Hernández Salazar, 2008). We decided to skip face-to-face discussions and hold the focus group by virtual means to take advantage of a global search for experienced participants. To manage group interaction and maintain the discussion's sense of immediacy while using a web conferencing tool, we reduced the number of simultaneous participants to a maximum of four. As O'Connor and Madge (2003) recommend, for conducting synchronous focus groups in cyberspace, the focus group was designed to last a maximum of an hour and a half.

Work from Montoya-Weiss et al., 1998, shows that diverse groups offer better results than homogeneous groups. Diversity seems to promote richer interaction through the generation and consideration of a broader range of ideas. Reid and Reid (2005) recommend forming groups with diverse profiles for research tasks, such as generating ideas. For this latter case, authors claim that online groups often outperform their face-to-face counterparts, both in the number and variety of creative ideas they produce. Nevertheless, Montoya-Weiss et al., 1998 warn that communication difficulties may arise in diverse groups that must be overcome by the moderator. We decided to use a single agenda for the four different groups. Participants were assigned to groups so as to maximize group diversity on the basis of experience and profile: we included subjects with and without technical background in each group, and we made sure each group included individuals from each category (engineer, designer, and artist).

2.2. Study preparation

The focus group materials were designed based on literature from both social sciences (Hernández Salazar, 2008; Montoya-Weiss et al., 1998) and information systems research (Lazar et al., 2017; Nili et al., 2017). Three premises, closely related to the objectives of the focus group, guided the content design process: (1) Define a set of open-ended questions to obtain information on design methodologies used by participants. We rely on this freedom to invite the respondent to answer in-depth, exploring their relationship to the use of sensing technology. (2) Make use of both content and interaction data in the form of verbal and non-verbal communication aimed to understand what issues interaction designers face when trying to interpret raw data from motion-based sensors. (3) Design the focus group less than fully structured, leaving the possibility to generate questions on the spot in response to specific comments with the purpose to identify how designers relate the sensing capabilities of technology to interaction design possibilities.

We prepared a focus group guide with questions in a logical sequence to meet the research goals. During brainstorming sessions, we grouped questions and synthesized them into four main questions that divided the focus group agenda accordingly (Table 1). The first three questions corresponded to the main objectives of the focus groups, and a fourth one was aimed at driving a participative ideation stage towards the end of the session. However, another six questions were used as supplementary prompts by the moderator to lead the discussion. The ideation process was designed as a collaborative creative effort, focused on getting rich insights on appropriateness, interpretability, and other design needs for novel motion-based features they would like to use in their work. We included an ideation phase to help participants to articulate their design needs more precisely and realistically regardless of their different backgrounds. Moreover, we sought in the dialogue with the participants, ideas of solutions to the problems raised in the use of feature extraction technology.

2.3. Procedure

The focus group moderator (the corresponding author of this study) contacted each of the selected participants in advance to explain the objectives of the focus group, complete the informed consent form, and agree with the participants of each group on a meeting time. The focus group sessions were conducted using a web conferencing tool, and

Table 1
Main and supplementary questions in each stage.

Stage	Main Question	Supplementary Questions
Stage 1	How do you explore the different behaviors of users to develop an interactive experience?	What interaction design methodologies do you use most frequently?
Stage 2	How do you relate interaction design to the possibilities offered by detection technologies?	How do you translate detection systems outputs into a feature representation especially suitable for use in a creative context?
Stage 3	When using motion-based detection technologies, do you think about interpreting the sensor data?	What interpretation problems from sensor data have you usually found?
Stage 4	Which design needs should a set of features solve when creating motion-based multiple-users interactions?	What features (information extracted from multiple-users movement) do you consider to be close to typical concepts of full-body interaction design in large-volume spaces? Which design needs should a set of features solve in the context of large-volume spaces and full-body interaction? What features, drawn from multiple-users movement, would lead interaction designers to explore the body as a communication/interaction strategy?

participants were encouraged to activate their webcams. Before beginning the focus groups, the moderator reminded participants that discussions would be used to guide the next stage of the research and that responses anonymity would be guaranteed. The first ten minutes were used for participants to introduce themselves. During this time, the moderator encouraged participants to share their professional backgrounds and experience as interaction designers. The moderator then presented the research project objectives and explained the word 'feature' in the context of this research. This was important as, given their diverse professional and technical backgrounds, the term might not mean the same for all participants.

The group discussions lasted one and a half hours, and the same moderator conducted all focus groups. All focus group sessions were recorded as video files using the web conferencing tool and later transcribed verbatim. The moderator did not take notes during the sessions; rather these were transcribed verbatim from the recordings. The full transcripts were then analyzed as detailed below.

2.4. Data collection and analysis

The focus group video recordings were initially reviewed numerous times while taking notes on statements and interesting quotes, as a method of immersion and preparation stage before the analysis. Authors like Vaportzis et al. (2017) suggest that such an immersion process allows familiarity with the language and wording used by the participants. Data analysis was conducted by the corresponding author, who was also the focus group moderator. The other three researchers reviewed the analysis criteria and validated all relevant decisions, periodically discussing until consensus was reached, to maximize the objectivity of the analysis. For the focus group analysis, we followed the framework developed by Nili et al. (2017), as we identified their work to be integrative and systematic. Nili et al. categorize focus group data into two main groups: content and interaction data, arguing that both can be found in the form of verbal and non-verbal communications. Content data refers to any participant comment or expression that can be taken at face value and does not require knowledge of any conversation/interaction that it may be embedded in, whereas interaction data refers to agreements, questions, challenges, or support among the participants, which usually are verbal manifest communication ideas (Nili et al., 2017). However, sometimes interaction data could also be expressed nonverbally through gestures, facial expressions, or even pitch and loudness changes in the voice. People communicate non-verbal information in social settings, intentionally or not, and such information enriches the receiver's perception of information that the encoder communicates via verbal means (Hall and Knapp, 2013). Thus, we considered non-verbal interaction data in the analysis.

Following the guideline and suggestions from Nili et al. (2017), we created a complete organization scheme of theoretically sensitive data with content and interaction information. The interaction data included annotations with verbal and non-verbal communications with a low level of precision. This choice is justified by the fact that, although the focus group was designed with an emphasis on group discussion, the individual opinion is the subject of analysis. The data organization scheme considered non-verbal content and interaction data in tandem with associated verbal data because there were situations where both data types considered together, represented a better understanding of the participants' opinions. Although non-verbal data by themselves are considered meaningful by some researchers (Onwuegbuzie et al., 2010), in most cases gestures and facial expressions wouldn't be significant without a match to verbal communication (Vaportzis et al., 2017). Finally, from this data organization scheme, we identified five main content areas (see Section 3 for further analysis and discussion), under which, all related text and non-verbal data from all sessions were merged to make the next phases of the analysis easier.

The next phase in Nili et al.'s framework (after identifying the content areas) is to conduct a manifest analysis of content data following a bottom-up approach (Nili et al., 2017). This phase of the analysis process consists of the following steps: (1) Identify meaning units within the manifest content of each content area. (2) Condense meaning units using a description close to their original text. (3) Label condensed meaning units with a code and sort them into categories based on similarities. (4) Express the overall interpretation of the underlying meaning for all categories in each content area via one theme. The whole process of meaning unit identification needed several iterations to highlight a phrase, sentence, or even a discussion segment that described a specific phenomenon. Going through the organization scheme of theoretically sensitive data a few times, we noticed a few themes emerging, which were developed by deductive methods. The following phase after the manifest analysis is to conduct a latent analysis of content data. In the context of the framework by Nili et al. (2017), latent analysis is the interpretation of underlying constructs through observable elements focusing on the implied value of the data via the researcher's judgment. Similarly as before, meaning units in the latent content for each content area are first identified. Then, a description close to the content area's original text and the interpretation of each meaning unit is annotated. Finally, based on similarities among meaning unit descriptions, they are abstracted by groups into one or more themes with a corresponding label to report how data is linked with each content area (Nili et al., 2017).

The final phase in the framework is the analysis of interaction data and the definitive integration of results by content area. For the first task, verbal and non-verbal data is obtained by reading through the data organization scheme. This analysis mainly focuses on: (1) identifying points of consensus or dissent with ideas expressed during discussions, and (2) interpreting the meaning of participants' interactions that indicate things other than agreement or disagreement (Nili et al., 2017). Lastly, to capture the overall results of data analysis for each content area, all categories from the manifest analysis, and all themes from the latent analysis in each content area are merged.

3. Results

The analysis of the organization scheme of theoretical sensitive data revealed general interaction designers' perceptions when using different motion-based full-body features. The five main content areas were: (1) User behavior exploration, (2) design methodologies used, (3) relationship between interaction design and sensing technology, (4) sensor data interpretation, and (5) motion-based features' design needs. The five content areas were common to all participants independently of their professional background or their previous technical experience. This section presents the content areas in the same order in which they were discussed during the focus groups and not by their importance, frequency, or uniqueness. Participants' quotes are presented below to illustrate each content area. To differentiate the quotes provided by academic background, those from engineers participants are denoted with an E, those from designers are denoted with a D and those from artists are denoted with an A. A summary of the content areas and categories is presented in Table 2.

3.1. User behavior exploration

Participants mentioned how they explore user behavior when developing an interactive experience in general. In this article, the exploration of user behavior consists of how designers support reflection on the experience of movement. When the design focuses on the human motion itself, a first-person perspective on the interaction design is required, closely related to the exploration of the user's movement possibilities. During the focus group, participants predominantly discussed their strategies about using the users' bodily motion during the conceptual design of an interactive experience. To a lesser extent, there was also discussion about their approaches to understanding the user's response to the experience design throughout the use of technology. Additionally, participants referred to such descriptions of the user's behavior as valuable information for understanding how to design/improve the system. Three categories emerged under this topic: according to the context (Section 3.1.1), based on the different actors involved (Section 3.1.2), and since the conception stage (Section 3.1.3).

3.1.1. According to the context

Participants noted that user behavior exploration is highly contextualized by for example space, the project requirements, or the detection

Table 2
Focus groups content areas and categories.

Content Area	Category
User behavior exploration	According to the context Based on the actors involved Since conception
Design methodologies used	Good practices Formal methodology In relation with others
Relationship between interaction design and sensing technology	Technological research Best resolved at the early design stages Design away from technology Technologically influenced design
Sensor data interpretation	Valuable for design evaluation Outsourcing Tool for fostering creativity
Motion-based features' design needs	Features presentation Multiple user features Single user features Criticism

system technology. Concerning the use of space, participants thought that it is directly related, and that manual observations of user behavior, in situ, are required.

E: "User behavior exploration arises from a particular need according to the use of space."

Some other participants consider it to be strongly dependent on the project target, as each project involves different dynamics.

D: "It is very dependent on the context, and each separate project requires a different dynamic."

A group of participants with a technical background agreed upon the belief that simplifying the actions that trigger an interaction facilitates the use of sensing technologies and the extraction of motion-based features. For them, the conceptual design of an interactive experience can start from the capabilities and limitations of technology.

E: "Starting from a certain technology capability, interaction ideas usually arise."

3.1.2. Based on the actors involved

Participants emphasized that user behavior should be explored taking into account a bigger perspective beyond the user himself. Three main actors should guide this exploration: (1) the public (users and non-users), (2) the client, and (3) the creator.

D: "The user will have specific characteristics, but we must not forget that the client is the owner of the reason for the interactive experience, and as such, he imposes certain commercial conditions. Finally, the designer's role is to take the natural behavior of the user to enhance what is wanted from the interactive experience."

E: "The starting point is always the experience objective. Based on what we need from the user, the best detection system is identified."

E: "A priority is the type of audience, and something that emerges from the above is the elimination of noise from other spectators around, who are not your users."

3.1.3. User behavior explored since the experience conception

Participants with an artistic professional background considered that user behavior exploration should be addressed on a multidisciplinary basis and as an integral part of the conceptual design.

A: "We usually explore user behavior as a multidisciplinary work and from early ideation and conceptualization stages. A total fusion between creative, technical, and design processes should be sought in artistic environments."

In the discussion of the above, some of the designer background participants argued that user behavior exploration should be considered an early phase of the design process, detached from technology. However, an artist participant dissented claiming that for him, technology has always been seen as part of the discourse of the artistic process.

D: "I conceive the interactive experience conceptualization very detached from the technical tool.It is at this stage that the broad outlines of physical space and user behavior are articulated."

A: "For me, the technological development of the interaction experience is a fundamental part of the artistic discourse."

3.2. Design methodologies used

Overall, participants consented that there is no general methodology that could always be followed to design interactive experiences, and most stated that it is very dependent on a multivariable context, as was shown before. Three mutually exclusive categories emerged under this topic: some participants were strictly dedicated to commenting on what they considered good design practices (Section 3.2.1), some participants discussed their methodological approaches (Section 3.2.2), and some others have seen in their relationship with other peers a design framework (Section 3.2.3).

3.2.1. Good design practices

In terms of perceived good practices, some participants with technical experience thought that lowering user frustration is determinant on choosing the detection technology, for example:

A: "The technology that reduces user frustration, that is the most determining factor in choosing detection technologies."

Some found, again, a relation with space while talking about good practices:

E: "As a methodology, it is customary to limit the space to certain areas where interaction is defined."

Some participants think that identifying emerging technologies and being attentive to future and developing trends allows facing new interaction design challenges with the latest available technologies:

D: "In digital arts, I usually work with things that I know that work because I have implemented them before."

3.2.2. *Methodological approaches*

Participants were less in agreement regarding the methodological approaches to design interactive experiences. It appeared as the subtopic with clearer differences between participants with different professional backgrounds. Some technical background participants held that their methodology is based on a constant conversation between technical development and design to fit client needs, user behavior, or space requirements.

E: "Interaction design is always a conversation between technical development and design."

E: "Design Thinking is my usual methodological approach. However, it is frequent that the first stages in the methodology are cut to comply with the efficiency requirements of the client."

E: "The client has an idea in his head and that is the real starting point, leaving behind creative steps such as empathize and explore."

A designer background participant showed a wider methodological perspective with three paths with different starting points (depending on the project priority).

D: "I usually take a different approach depending on the project priorities: (1) Based on the content that must be presented to the user, (2) according to specific interaction requirements, or (3) according to the emotion you want to convey."

An artist participant shared his design methodology based on ‘play and improvisation’ and talked about the necessity to establish a communication/collaboration system between members of multidisciplinary design teams to define a technical-creative language.

A: "I use play and improvisation [...], then it is important to be able to establish a collaboration system among the design team that helps define a technical-creative language."

3.2.3. *Working with others*

Participants with little technical experience noted that working with others is a common artistic practice:

A: "Collaborations cannot be set aside. To cover a wide spectrum of possibilities we need the support of other artistic profiles."

A: "I stopped programming in my projects when I realized that there are plenty of talented developers and digital artists I can work with."

3.3. *Relationship between interaction design and sensing technology*

For most participants, the role of the interaction designer during ideation stages is seen as the link between members of a multidisciplinary team who come from human sciences (Eriksson, 2010) or even graphic design and computer systems programming. In this context, we perceive from practitioners’ discussions that in the multidisciplinary design teams they have worked, not all members are interaction designers, nor do they have a design-oriented attitude towards movement interaction. Four categories emerged under this topic: technological research (Section 3.3.1), technological influenced design (Section 3.3.2), implementation strategies are best resolved at the early design stages (Section 3.3.3), and design away from technology (Section 3.3.4).

3.3.1. *Technological research*

For some participants, interaction design must be fueled by a constant evaluation of novel tools and emerging technologies to increase the ability to propose new interactions.

E: "At first, the interaction designer’s experience comes into account to make decisions when making this relationship. There is also a stage of constant technology scouting to understand and manage new technologies, before being able to offer it to a client."

E: "A continuous search for technical possibilities must be made to provide a solution to the client."

3.3.2. *Technologically influenced design*

Similar to previous technical background participants’ thoughts, some designers held that technology influences interaction design.

D: "It is impossible to be creative with something unknown. At least an influence of the visual technological culture is necessary when designing."

D: "There are technological platforms (websites) that are of great help when designing. Examples like Pinterest and Vimeo allow having references and ideas of what has been done in terms of interaction design and technical development."

In that sense, technical background participants presented harder opinions, like:

E: "You must have at least knowledge of the technological context and what is happening in terms of sensing technology, to design interactions."

3.3.3. *Implementation strategies are best resolved at the early design stages*

Some participants considered that taking decisions about which sensing technology to choose should be resolved at the early design stages, as the following comments suggest:

E: "From the ideation process, you must think about the implementation to meet the design requirement. In the materialization, there must already be a decision made based on the available economic resource that determines the technological capacity."

A: "Interaction design is a multidisciplinary work. Ideally, you should have several of these actors in the design process from the beginning: developers, user psychologists, and audiovisual designers."

A: "Collaborative work methodologies must be built between creative and technical profiles to harmonize design and implementation from the ideation stage."

3.3.4. *Design away from technology*

Other participants were skeptical about giving such a big relevance to technology, in a clear minority position against most participants.

D: "Creative processes must be detached from technology, so as not to fall into doing only what the machine allows. First, you have to think about what the audience is going to feel or experience."

A: "As interaction designers we must first focus on strengthening the concept, rather than choosing a sensor. I usually try to minimize dependence on technology during design, which usually results in a stronger concept."

3.4. *Sensor data interpretation*

There was a consensus between participants with implementation experience, arguing that knowing the nature of sensors and their output data is essential to complete an efficient development cycle. Three categories emerged under this topic: Valuable for design evaluation (Section 3.4.1), outsourcing (Section 3.4.2), and usefulness in artistic contexts (Section 3.4.3).

3.4.1. *Valuable for design evaluation*

While expressing their thoughts about interpreting sensor data, participants referred to their own implementation cases for sharing ideas. Some participants argued that collecting data for evaluation of the interactive experience itself is a plus:

D: "The possibility of having data on the behavior of users, allows us to evaluate the interactive experience design. If we think about the client's needs, it becomes a valuable product to offer."

D: "The use of motion-based features can be helpful to validate whether the user reacts as expected in scenarios such as virtual reality. You can think of this as valuable information for understanding how to improve the interaction design."

For a technical developer of interactive systems, knowing both detection system nature and sensor data format is crucial to complete an effective development cycle, as the following comment suggests:

E: "It is very important to identify the type of information that a sensor provides, to later obtain an interpretation that suits the concept of the interactive experience."

3.4.2. *Outsourcing*

Asking the participants about the sensor data interpretation revealed that some participants with technical background relate the data interpretation with outsourcing and third party software tools. Some of them prefer extensive use of SDKs and libraries to transform raw data into the required abstraction level and carefully choose a detection technology with the goal of reducing user frustration while interacting with the system. As the below comments suggest, time investment and complexity are primary concerns in the use of feature extraction technologies:

E: "Due to time management, we do not process the raw data on our own. We are always using SDKs, libraries, and software assets to bring the raw information from the sensors to the level required by the interaction design."

E: "We define what sensing technology to use based on reducing user frustration. We prefer to use an SDK or library to process raw data rather than develop it ourselves."

Participants expressed concern about the generalization of motion-based features' use. One participant considered that generating features for universal use in the context of interaction design is very difficult, while another held that a closed set of features will be useful only in specific contexts when linked to a certain application.

A: "I can't imagine if a list of descriptors can be so general that they could be used in all cases. Hence, the dependency with each interaction project is shown."

3.4.3. *Tool for fostering creativity*

Participants from all backgrounds emphasized that sensor data interpretation can be a differentiating factor and lead to creative processes that promote technological diversity even for non-technical practitioners. Participants expressed that, increasingly, there is dependence on software libraries developed by third parties for interpreting sensors and increasing production capacity. Somehow, this technical dependence is responsible for alienating interaction designers who have no coding skills but represents a tool that fosters creativity for those who do.

E: "The interpretation of the sensor data can be a differentiator factor and lead to creative processes."

A: "The experience of using ROS (Robot Operating System) may seem complex, but then the possibility of manipulating data with different programming languages, leaves the feeling that there are millions of possibilities that in the art world are not known at all."

D: "In a specific case that I was faced with, studying the nature of the sensor data allowed me not only to make better use of my detection system but also to relate the capacity of the sensor to the interactive concept."

3.5. *Motion-based features' design needs*

The moderator guided the last stage of the focus group as a participative design process. We attempted to actively involve all participants in this process to help ensure the result meets their needs. We exposed participants to an initial exploratory question to focus on ideas for a solution. Through the discussion, three themes emerged: single and multiple users features (Section 3.5.1), presentation of features to an interaction designer (Section 3.5.2), and criticism (Section 3.5.3).

3.5.1. *Single and multiple users features*

Some participants made the distinction between features for single and multiple users, and the following ideas emerged as possible features for the first case:

E: "Statistics of the behavior/movement of users in front of commercial spaces."

A: "I find it interesting to have descriptors with high semantic capacity, to discriminate user actions."

A: "The possibility should be left open to record certain personalized poses and make something like a matching template to recognize particular poses according to each need."

Then some participants' ideas regarding features for multiple-users focused on user flow, movement patterns, and grouping.

A: "I imagine features to understand movement through individual, dual and plural relationships between users."

E: "All kinds of features for flow analysis.How users group and circulation patterns."

E: "I would like to have features to identify crossings between people."

D: "Interesting having feedback on movement or posture similarities between users."

3.5.2. *Presentation of features to an interaction designer*

Overall, participants showed interest in discussing how a set of features should be presented to non-technical interaction designers to facilitate its appropriation and use.

E: "Features should be presented according to the interaction designers' ability to understand the abstraction process."

D: "Many possibilities are interesting, but having a reduced view with the most popular features first, allows a faster approach to technology."

E: "The set of features can be hierarchically organized by levels of abstraction, with features in at least three abstraction levels."

D: "A list of possibilities allows you to identify a path to design when you are not a technology expert."

D: "The semantic capacity of the feature is essential for the designer. If the tool is for designers, it is very important to use the language that the designers understand."

3.5.3. *Criticism*

A few participants were skeptical about interaction designers' overreliance on technology, and whether complex feature extraction is necessary:

E: "As a personal conclusion and in response to the comments of the other participants, I consider that having features far beyond simple speed or acceleration would not have been useful in interactive experiences like the ones I have developed."

A: "An algorithmic proposal that characterizes the user and that may serve in the design of the interaction, is not an approach that has been implemented in projects that have recently surprised me. Quite the contrary, they have come from user behavior studies or interactions observations in physical space."

4. Discussion

This study explored the relationship between motion-based feature extraction technology and sensor-based interaction design methodologies used by practitioners, as a potential tool to define novel interaction inputs and foster user behavior exploration. Our findings extend previous research that investigated the perspectives and attitudes of interaction designers toward the use of user data in multisensory experiences

(Seifi et al., 2020; Vilaza and Bardram, 2019). Previous work from Vilaza and Bardram (2019) focused on designers' perspectives on shared health-data access, Seifi et al. (2020) focused on novice practitioners' design needs for multimodal haptic feedback, whereas we focused on how perceptions and barriers to movement-based interaction design are formed, and therefore incorporated a more practical element to understand how the practitioners' background shapes the perception of the role of technology. Our focus group sessions considered interaction designers' perceptions about how they might use human-interpretable features as a potential tool to explore user movement, in addition to highlighting general attitudes toward sensing technology and sensor data processing, and what might hinder or facilitate using multiple-user motion-based features.

Some content areas that emerged in this study were consistent with the literature. For example, "Technologically Influenced Design" emerged both in the current study and also in the work by Sørum (2017), although the latter labeled the theme "Contribution to Products of the Future." In both studies, participants held that it would become more valuable for interaction designers to have knowledge not only in design but also in the technology field because of the increasingly interdisciplinary nature of work. In terms of design, participants in Sørum (2017) which were all interaction design students, viewed it as crucial to have good knowledge of the technology to enable the creation of innovative solutions. Opinions about design teams' formation and preferences for including people with different approaches and fields of interest were also noted in both studies. A common content area with previous work by Owusu et al. (2012) was the perceived impact of choosing and applying design methods. Interestingly, researchers found not only that flexible use of methods by expert designers leads to better performance, but also that the level of freedom in using methods influences novice and experienced practitioners differently (Owusu et al., 2012). Consequently, our study evidenced a consensus among participants that there is no general methodology that could always be followed to design interactive experiences, as it is perceived as a very context-dependent task. As participants mentioned, they preferred to trust their skills and common sense to guide each particular design process.

To point out how the findings of the study are useful for designers to create new interaction paradigms using the sensing capabilities that feature extraction technology offers, we first establish a relationship to the work by Sundström et al. (2011). The authors argue that although the mediums' properties need to be considered in any design process, technologies are usually black-boxed without much thought given to how their distinctive properties open up design possibilities. Sundström et al. (2011) supported their study claiming that computing technology is a more complicated material for many designers to work with (Ozenc et al., 2010), and we corroborated this idea. In the context of working with motion-based features, we perceived from participants that they are not very familiar with feature extraction technology as a design material which explains why only technical practitioners feel comfortable using feature extraction technologies even though they depend on tools developed by third parties. In addition, we found that participants with a design background have not paid attention to exploring and thinking imaginatively about the reach of feature extraction technologies and, consequently, they showed doubt about interaction designers' overdependence on technology. We sought to identify defining aspects of motion-based features during the discussions with participants and then tried to find out how to reduce the technical effort from designers while experimenting with different extraction possibilities. Perspectives from participants showed that finding a design-oriented approach to present feature extraction capabilities to non-technical interaction designers should facilitate its appropriation and use. Moreover, interaction designers were interested in having tools that may help identify a path to design when using motion analysis algorithms. In a scenario where performing an action without implementation is fundamentally different from performing that action with feedback from technology and in the presence of tracking errors and limitations that are inevitable with movement-based technology (Gillies, 2019), practitioners acknowledge the importance of getting a sense of technology as design materials before being used on a working prototype, especially for those that consider themselves as not technology experts.

Through the analysis of the participants' perceptions about methodological strategies for interaction design, it was clear that motion-based interaction relies on a variety of approaches that depend on the design context. Proof of this was the differences in discussing methodological approaches for designing interactive experiences. For most interaction designers with technical expertise (i.e., participants with an engineering background), technology-mediated design approaches allow incorporating a value of the moving body. We consider this perspective on interaction design in closer correspondence with "design by doing and moving" strategies (Gillies, 2019; Hummels et al., 2007) than the more representational approaches of pragmatic-account participants (i.e., interaction designers with a design background) who design movement-based interactions detached from technology. Regarding sensor data interpretation, participants from all backgrounds coincided and argued that it is a determining factor to encourage creativity. Similarly, Hummels et al. (2007) believe that designers need design methods and skills that help explore and reflect on innovative interactions and consequently present tools such as the Design Movement approach that supported and inspired novel movement-based interaction paradigms.

By asking participants how they handle technical issues while working with movement recognition technologies, we identified the importance they attach to sensor properties, such as effectiveness, interpretability, and predictability. If we relate this perspective to how participants inform design, we saw that they think it is hard to be creative with something unknown. The contribution of Sundström et al. (2011) provides a methodology to resolve such an issue by fostering exposure to one or several of such dynamic properties considered as digital material. In other words, they advise designers to get a sense of technologies before becoming part of a working prototype. O'hara et al. (2013) go deeper by drawing on the theories of embodied interaction and situated action and concern about how properties of the technology and the social system are combined in the production of meaningful and natural interaction. As pointed out by an art background participant, collaboratively work methodologies built to implement co-design strategies between creative and technical profiles in design teams may help bridge technology and material world to configure interactions in new and meaningful ways. In articulating this, we see the bodystorming scenario of the Embodied Sketching practice (Márquez Segura et al., 2016) as conclusive by encouraging designers to engage physically in co-design play-based ideation activities with peers to help sketch ideas for movement-based interactive systems.

Most participants considered that diverse and categorized motion-based features may facilitate user behavior exploration and emphasized the likelihood of using a feature extraction system with such characteristics in the future. The positive assessment of participants was further evidenced by the fact that all of them came up with ideas to meet their own design needs while in the participative design process at the end of each focus group session. Despite that, participants expressed concern about the general use of a motion-based feature closed set, knowing that interaction design is very dependent on a multivariable context. It was evidenced from participants' discussions that there is no general methodology that could always be followed to design interactive experiences and that certain sensor data descriptors will be useful only in specific contexts when linked to a certain application. Overall, participants with a background in design conceive the ideation process detached from technology. However, practitioners coming from the arts held that user behavior should be addressed on a multidisciplinary basis and considering the use of technology as part of the artistic discourse. Some were skeptical about the interaction designers' overreliance on technology, and whether complex motion-based features are necessary to design memorable interactive experiences.

Our findings are useful to inform developers of computational tools for interactive system creation about motion-based feature refinement, thereby increasing the acceptance and adoption of higher-level features by interaction designers. Focus group participants proposed several such features, solving design needs that are worth consideration. For example, analysis of full-body movements to discriminate between multiple-users actions. Our participants did not reach a consensus in terms of how to describe multiple-user movements through feature extraction. Some participants asked for people-crossings counting, others required all kinds of features for users' flow analysis, and others showed interest in circulation patterns similarity and users' clustering in space. Another point for refinement is related to feature layout and presentation. A system for interpreting user-motion data should present features hierarchically organized by levels of abstraction and according to the interaction designers' ability to understand the extracted characteristic. Participants argued not only that a neat-presented feature set is relevant for non-technical people to favor their appropriation and use. But also that a curated list of possibilities allows practitioners to identify a path to design when they are not technology experts. Finally, from the analysis of focus groups, we argue that if we want interaction designers to understand what motion-based feature extraction technology is capable of, two things are needed: (1) Developers of computational tools for interactive system creation need to work on the interpretability that designers can make of motion-based features extracted by the system; and (2) designers must recognize features' distinctive properties by experiencing them in an embodied form. By doing so, we can envision *designer-interpretable* features as a potential tool to foster user behavior exploration.

5. Conclusions

We found that practitioners consider that processing sensor data to extract motion-based features is challenging and time-consuming. Moreover, only a few professionals with appropriate technical backgrounds feel comfortable using their own feature extraction algorithms in their interaction design work. However, most participants were eager to use a computational tool designed to interpret multiple users' motion from diverse perspectives, meaning that novel interaction strategies might emerge from a broad user-motion description capability at a reduced technical cost. Furthermore, to increase the chances of adoption, motion-based features should be grounded in conceptual frameworks known for offering advice on designing sensor-based interactions. Nevertheless, non-technical interaction designers should be aware that acknowledging the detection system's nature and being able to follow the possibilities opened up by technology is crucial to complete an effective design-development cycle. Overall, the current results are consistent with the objectives of our study. Based on the relationships that professionals currently make between sensor-based interaction design and feature extraction technology, it is possible to design a computational tool to reduce the technical effort of designers to characterize the movement of the user. Finally, it has been validated from the participants' opinions that such a computational tool, conceived as a *designer-interpretable* motion-based feature extractor, constitutes a comprehensible representation of the interaction design possibilities that the sensing technology offers.

This research sheds light upon the effect of motion-based full-body features on interactive experience design by evidencing practitioners' approaches towards computer vision technology. With our study, we position feature extraction technology as a useful tool to better understand user behavior when designing interactive experiences, but also we acknowledge its limitations. Further investigation on how to relate interaction designers' needs with feature extraction technology capabilities is necessary to enhance the scope of the research and further refine its findings. Research into solving this problem is already in progress. Future work will explore the practical implications of using a computational tool designed to interpret multiple users' motion on practitioners' interaction strategies.

CRediT authorship contribution statement

Antonio Escamilla: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft. **Javier Melenchón:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Carlos Monzo:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Jose Antonio Morán:** Conceptualization, Methodology, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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