



Article

Creative Probes, Proxy Feelers, and Speculations on Interactive Skin

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Abstract: This paper critically discusses the combination of creative and social research methods to generate a novel approach to explore the multimodal technoscape. This paper draws on an interdisciplinary exploratory case study on interactive skin—an emergent technology that augments and/or interacts with the skin. This paper shows how concepts from skin studies and the HCI literature can be used to draw on creative methods to think about and with the body. We describe the use of an online probe pack, a speculative research workshop and sensory research interviews using ‘proxy feelers’ to agitate the design space of interactive skin futures. We show how combining these methods provoked and expanded the scope of interactive skin from the technological to the sensory and the social. We discuss the opportunities and challenges of the research dialogues that this approach facilitated, make the case for creative methodological improvisation and exploration of emergent technologies and show how creative and social research methods can be combined to explore the interconnection between technology, society and design.

Keywords: multimodal; sensory; creative methods; cultural probes; online research; speculative methods; futures; interactive skin; emergent technology; body



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1. Introduction

This paper makes the case for creative methodological improvisation and exploration of emergent technologies and shows how creative and social research methods can be combined to explore the interconnection between technology, society and design. This paper critically discusses the use of creative research methods for exploring the relationship between body and technology in the context of human–computer interaction (HCI) where design and fabrication processes are focused on the body [1]. This paper uses the exemplar of interactive skin—an emerging class of skin-worn epidermal devices that directly augment and/or interact with the human skin and body [2]. A ‘closely-coupled system’ of users and technology at the ‘blurry boundary between human and computer within a wider physical, digital, and social context’ [3].

This paper reports on an exploratory case study. Fieldwork was conducted remotely (online) over one month in a research lab specialising in interactive skin. This paper demonstrates the use of concepts from social skin studies and HCI to foster interdisciplinary research in the form of a novel creative approach. This involved the use of an interactive skin creative online probe pack and a speculative research workshop on interactive skin futures alongside a lab tour and sensory research interviews to agitate this technological design space.

2. The Background

2.1. Interactive Skin

Advances in HCI, new materials, electronics, sensor design and fabrication (e.g., printed flexible electronics and flexible capacitive sensor matrices) have led to the emergence of

electronic devices that reside directly on the user's skin [1,2]. Interactive skin is an emerging class of skin-worn epidermal devices that interact directly with and augment the surface of the human body. Interactive skin technologies are very thin sensor overlay (often thinner than a human hair), made from bio-compatible, flexible, robust, and deformable materials. They are designed to feel natural by preserving tactile perception, stretch with the user's skin, and to continuously monitor physiological parameters [2]. To harness the body's capacitive properties and ensure technological robustness, interactive skin utilise a range of fabrication strategies and processes.

Conceptually, interactive skin is fundamentally different from conventional 'off-body touch surfaces' as the skin's physiological qualities (e.g., stretch-ability) afford a broader input space for on-skin interaction (e.g., press, grab, twist, and scratch) [4]. Unlike other wearable devices, interactive skin feels and behaves like parts of the body, the user interacts on their own body through interactive skin, blending bodily movement and haptic perception with computer-generated tactile and visual output. The physiological properties of skin, combined with people's strong personal and emotional associations with the skin, contribute to shaping interaction with interactive skin. The skin's properties and associations vary across parts of the body, making body location key for the design of interactive skin [4,5]. Interactive skin thus sits within the broader field of human-computer integration in which computational and human systems (i.e., the body) are closely interwoven [3], and opens up a new interaction space, whose input/output modalities and capabilities are emerging but largely unexplored.

Interactive skin technology is at a relatively early stage of development and, to date, research has primarily centred on the development of suitable materials and fabrication techniques. There have also been explorations of application domains spanning hyper-mobile computing, health and well-being, sports and fitness, and tactile augmented/virtual reality. Early interactive skin studies investigated the characteristics of the skin-specific input modalities and locations to analyse the types of gestures that are performed on the skin. This work accumulated in the following design goals that were proposed by [4] and continue to influence the field: skin compatibility; arbitrary locations, but with three primary locations—hands, arms and head (with the forearm and hand identified as preferred locations for on-skin input); easily detachable; visual customisation; accurate and multiple inputs (e.g., two levels of touch pressure and swiping); compatible with output devices; and scaled-down processing units.

Early prototype designs included a finger strap for accepting incoming calls, a roll out keyboard for typing on watches, a skin music player worn on the arm, and a headset control worn on the skin behind the ear [4]. Skin marks [5] were developed for more precise and localised input and output on fine body landmarks in the form of rub-on tattoos. Such materials better enabled devices to conform to wrinkles and are compatible with curved and elastic body locations. The skin marks sought to provide users with feedback through proprioceptive, visual and tactile feedback to support fine interactions, guide particular types of interaction, and support recall. This work led to the development of Tactoo a very thin feel-through interface for electro-tactile output on the user's skin [6]. Tactoo enables novel types of on-skin interfaces that provide dynamic tactile output in response to a 'growing demand for feel-through tactile interfaces' that fits in with users lives which are hyper-mobile, discreet and robust. The recent development of ever thinner and flexible sensors that are customisable (e.g., in shape and size) and that offer multitouch on-skin input has further opened up opportunities for direct, subtle, and expressive interaction [7]. Recent work has also focused on the development of do-it-yourself fabrication of skin-conformable interfaces [1,8–10]. These developments seek to support users across application domains to custom make rapid interactive skin prototypes through on-body design, through for example computer-assisted visual guidance that accounts for circuit logic [1].

Another stream of research focuses on understanding how skin-worn devices affect tactile perception; for example, Nittala et al. [2] found a correlation between the rigidity of

an interactive skin device and the user's tactile sensitivity threshold. The study findings were used to derive design recommendations on how to balance and combine tactile perception with device robustness. The notion of social acceptability of on-skin devices has been highlighted as an area of attention in the next steps in human–computer integration [3] and electrode garments [10].

With the evolution of interactive skin prototypes getting 'closer' to the skin and with designs taking inspiration from body art and tattooing, it is no surprise that the 'social' is coming into sharper focus. Such practices have been longstanding areas of interest in skin studies (reviewed later) as have themes of body locations and skin markings that inscribe identities (e.g., individualistic and/or tribal). The emerging areas of study for on-body co-creation and computer-facilitated design only serve to distance interactive skin from traditional mobile computing and newly connect this emerging class of multimodal technologies to skin and society.

As this brief overview of related work suggests, the field of interactive skin is rapidly expanding and raises new questions for technology, its societal and design implications [3]. Given the fusion between human body and computer, the design of this category of human-compatible technology would benefit from a deeper understanding of the social and sensory aspects of its design and use.

2.2. Creative Methods

The design space opened by emergent multimodal technologies, such as interactive skin, unsettles the boundary/interface between the human body and computing. Such uncertain spaces drive calls for 'lively' social research methods orientated to the unfolding 'becoming' of the social world [11,12] and have heralded many methodological turns. There have been turns to the multimodal [13], multisensory [12,14], 'non-representational' [15] and 'more-than-representational' approaches [16] and 'messing methods' [17]. These turns signal a dissatisfaction with the limits of social research methods [18] and seek, albeit in different ways, to engage with the complexity of lived experiences beyond language. This has intensified social researchers' interest in mobilising creative and imaginative methods to disrupt social research practices [19,20]. The approach discussed in this paper draws on two creative approaches—online probes and a speculative approach, both of which have been used in social research on 'emerging and uncertain' digital futures [21,22].

2.3. Online Probes

Online probes (or 'digital probes') are a method in which participants respond to open-ended 'evocative' tasks designed to provoke and engage participants in less linear and more novel interaction [22]. They are an adaptation of cultural probes, which originated as a design approach and method which challenged traditional 'problem–solution' trajectories in commercial design and HCI [23,24]. Cultural probes have been developed as a method within interdisciplinary social research, used in design sociology [25] and arts-based ethnography [26], usually with conventional social research methods (e.g., interviews or focus groups) [27,28]. A key difference between online probes and cultural probes is that the researcher provides the tasks but not the materials (although they may suggest or send materials to participants) [22]. Online probes (herein referred to as 'probes' for simplicity) have a largely optional nature, participants are given a range and asked to choose which they respond to. Probe tasks can take the shape of instructions or questions and are designed to be playful, open-ended—avoiding asking things which generate unambiguous answers, are intended to be enjoyable to respond to, and use a variety of modes. With online probes, participants draw on their own materials and this can lead to more diverse responses [22]. Probes can be introduced through an online or in-person meeting or workshop.

2.4. Speculative Design

Speculative design is an approach focused on producing insights on future possibilities that can act as catalysts for discussion of the kinds of futures people want [29], rather than working towards the materialisation of a future product. The approach is designed to provoke contemplation, examination of values, implications and ethics, and foster collective reflection through doing/making, for example, on the role an existing or near-future technology plays or might play in our lives [30]. More generally, a 'speculative register' is underpinned by a shift in focus from 'the probable to the possible' and informs the development of inventive approaches that involve the 'tuning of research techniques and engagements' [31]. The speculative process is an 'informed projection' grounded in knowledge of emerging trends, technologies and people's behaviour [32]. This resonates with social researchers' call for 'lively' methods to investigate the 'open-endedness of the social world . . . its' on going-ness, relationality, contingency and sensuousness' [12]. Speculative approaches also work to envision or craft futures 'which may not yet currently exist, to provoke new ways of thinking and to bring ideas or issues into focus' in digital education [33].

We bring speculative methods into conversation with the concept of 'sociotechnical imaginaries', a conceptual tool with which to investigate shared visions of desirable futures and resistances against the undesirable 'animated' by science and technology [34]. Future digital innovations, such as interactive skin, are concerned with engaging with the sociotechnical imaginary of designers and the public [35]. The sociotechnical imaginary generates a discursive space, which 'oscillates between imagination and reality' [36] and which is particularly salient for emergent technologies and enables us to approach the contemporary configuration of interactive skin as a moment of social and cultural reflection.

3. A Novel Approach: Methodological Findings and Discussion

3.1. Introduction

The interactive skin case study aimed to better understand the social and sensory implications and potentials of interactive skin. The case study sought to describe the social, sensory and semiotic aspects of interactive skin and its design; and to offer socially orientated critique to inform future designs of interactive skin. In addition, in response to researching during the COVID-19 pandemic, the study set out to contribute to remote sensory research methods. The case study was conducted in an HCI lab consisting of researchers with backgrounds in computer science, HCI, design and engineering. The lab was selected as it is a central node in the field of interactive skin (i.e., connected to other international research labs via researcher mobility and projects). The study participants were HCI researchers rather than end users of interactive skin technologies in order to focus on the professionals engaged in the ongoing production of emergent digital devices. Our rationale for selecting these participants was to capture a range of disciplines and experiences as a lens through which to construct overarching sociotechnical imaginaries of interactive skin. The lab was recruited via an initial meeting with the lab leader, where we outlined the case study. The invitation to participate was extended to the (seven) lab members working on interactive skin. Participation was voluntary and a process of informed consent was undertaken, with an information sheet and a consent form sent prior to the start of the study. All lab members (eight in total) agreed to participate. Their specialisms and foci included technical work on the development of sensors and materials (3), skin-based design techniques (2), haptics and interaction design (2), critical and speculative design (2), and the social acceptability of interactive skin (1).

A novel three-phased approach was developed to foreground the social and sensorial aspects of the relationship between body and technology in novel creative ways. The decision to move the study online due to COVID-19 restrictions impacted the approach as it changed the possibilities for interaction (e.g., casual hanging out and 'being there' afforded by the originally planned physical visit); however, it also stretched the process of engagement from a one week visit to a one month encounter with the team. This allowed

us to introduce the skin study concepts across a series of research encounters and for these to be cumulatively ‘fleshed out’ through activities. The shift to online research also raised challenges for the use of sensory methods and required the case study methods to be adapted (outlined below). The three-phase approach places creative methods within a multimodal [13] and sensory [16] frame, which share a qualitative attention to meaning beyond language, bodily interaction and the felt [37], and attend to participants’ first-person perspective on the sensing-touching body, and the technological and material constraints that shape experiences. The approach focused explicitly on the sensory and the social through creative, reflective and empathetic methods of attuning to one’s own experiences, which both compliments and distinguishes it from user-centred design methods used within the lab and HCI more generally. The three phases of the approach are outlined below.

3.2. Phase 1: Grounding

This initial phase mapped the participants’ conceptualisation of interactive skin including their use of working concepts, vocabularies and research methods, and their projects. The visual limitations of being online meant we had to gain other entry points into their practices and ways to bring in touch and the body more generally.

Research literature: Participants were invited to review and add to a shared online folder containing their papers and biographical information (i.e., research themes and interests, projects, collaborators, disciplinary training/background, and languages spoken). A review of this provided a sense of the key themes across the team, differences between participants and networks within the team.

Lab tour: Using Zoom on his mobile phone, a participant took the authors on a real-time (1 h) guided video walk tour of the lab rooms and facilities. He detailed the purpose and use of various machinery, technology and materials in lab spaces. He chose where to take us and what to show by directing his phone camera (‘our eyes’). As this fieldnote excerpt suggests, the tour experience was different to ‘being there’: “I found it hard to interrupt not wanted to break interesting descriptions, finding a gap/appropriate time, not being rude: this is very different to the subtle cues that you can do while present”. To expand the sensory possibilities of the tour, throughout, we asked our participant guide to describe and demonstrate the texture of materials (e.g., the viscosity of inks), manipulate (e.g., stretch or drape) materials, demonstrate the use of devices (e.g., how they are held); and at times, we asked him to bring materials or objects closer to the screen. In this way, the tour became an immersive sensory experience, albeit one constructed through the eye of a camera and the feel of another, and without the serendipity of ‘being there’, noticing and touching, smelling a process, asking what is behind a door or engaging with a passerby. Nonetheless, the tour contributed to our understanding of the sensory and technical environment involved in the production interactive skin.

Sensory interviews: In-depth sensory interviews were conducted with each participant on Zoom. Interviews were between 49 and 65 min (excluding introductions), an average of 55 min, and a total of 6 h and 20 min of interview data was collected. Interviews used an open topic guide focused on understanding how participants approach the skin in their research and if/how they engage with the social and sensory aspects of skin/interactive skin. Topics included ‘unpacking’ key research/design themes, reflections on design goals, and aspects of the social use of interactive skin (e.g., intentions, body location, users, and ethics). The interviews used objects as tactile sensory probes to help participants recall, ‘flesh out’, and ‘reconnect’ with the skin, touch and the body. This experiential method draws on the notion of sensorial empathetic research encounters with a participant’s sensory world to explore their experiential experiences [16].

We interviewed participants in a place where they had access to significant objects and materials related to their current work (e.g., prototypes or props)—this varied between home, studio, and lab. Participants were asked to use these objects as material prompts to think through or to demonstrate an idea or process during the interview to help elaborate

on the discussion. Our reflections on their use in the online Zoom environment shaped how we brought these objects into the interviews and evolved over time.

Participants interacted with these sensory touch objects (Figure 1) intuitively and occasionally in response to the interviewer's prompting. They used them to demonstrate or re-enact an experience or process or to illustrate a tactile feature (e.g., thinness and flexibility), concepts (e.g., social acceptance and skin markers) or ideas (e.g., manipulating objects to show how the body interprets and categorises sensation). While the visual display of tactile interaction afforded by Zoom and the empathetic character of sensory research encounters offered a relatively weak pathway to participants sensory experiences, we sought to strengthen this by introducing the method of 'proxy feelers'. The 'proxy feelers' method was developed in the larger InTouch project, initially in response to the difficulty participants experienced in articulating their touch experience in a case study of virtual touch [38], and later through a case study exploring robotic touch where the approach was tested and refined for remote (online) interview contexts to manage the tactile paucity of online research encounters [39]. The method consists of a three-part process. First, participants are invited to Demonstrate an idea/action and the interviewer mimics these using a proxy material to generate questions on the experience. Second, participants are invited to Feel the object while the interviewer probes to gain a sense of touch that extends beyond texture and cutaneous sensations to the social and sensorial. Third, participants are asked to Disrupt the function of the object they are handling or to suggest a usage that would alter or disrupt it. The following prompts for 'proxy feelers', for example, were used when asking participants to reflect on their consideration of the body placement of an interactive skin device: (1) Demonstration: Where would you think of placing it on yourself? Can you hold it against that part of your body? How visible/hidden is it? (2) Feel: How does it feel to have it there on your body? How might that feel during the scenario you have designed for? How do you imagine your intended user feeling? (3) Disruption: How do you imagine [chose a different context/person] would feel? The interviewers used props (e.g., cling film, stretchy materials and objects at hand) in mimicking participants' actions through the 'demonstrate, feel and disrupt' process to prolong and probe the social and sensory aspects of their interactions. Participants found this approach powerful and useful:

"I've had these materials in my hands several times. But not in a way where I really carefully concentrated on what happens when I am feeling ... [in my project] I was thinking more about the technical properties of the materials that I want to use, but now consider the appearance or the feeling that we get from these materials that we are using". (P8)

Participants were keen to bring their objects/materials into the interview although they sometimes found it hard to introduce them. Initially, we also found it difficult to bring these materials in 'naturally' and our mimicking movements confused and distracted some of the participants who thought the interviewer was trying to signal something or interrupt. In response to this shared difficulty, we introduced a brief explanation of the use of objects, materials and this 'empathetic' method in the interview, and we sought to bring our and participants' objects as early as possible, and explicitly negotiated this process with participants.

Discussion Phase 1

A preliminary thematic analysis of Phase 1 materials was undertaken and a set of emerging working themes were developed to capture the participants' collective inspirations (e.g., wearable technologies, synthetic materials, and science-fiction narratives), vocabularies and concepts (e.g., social acceptance), and practices (e.g., tattooing, low-fidelity on-skin prototyping and critical design). Emergent themes included the technology constraints and possibilities (e.g., sensor design); the 'skin as a boundary' between technology and human as an ethical line not to be broken; visibility—discreet, detachable, and unobtrusive devices and interactions; skin hacking and augmentation; the compatibility of interactive skin with the organic and natural; connectivity and connection; body 'landmarks'

and the location of interactive skin devices; tactile aesthetics; materiality (e.g., durability); and the care of skin/interactive skin. These working themes informed the development of the 'interactive skin probe pack' (Phase 2) and the starting points for the speculative workshop (Phase 3). They also pointed to the potential of creative research methods for exploring the relationship between body and technology.

3.3. Phase 2: Probing

This phase centred on the development and launch of the interactive skin probe pack. A set of seven creative probes (or tasks) were designed as a provocative research tool to facilitate participants (and researchers) to explore the social and sensory aspects of the skin in novel creative ways to open new spaces for research/design and to gain an impressionistic account of participants' associations and beliefs, social and cultural concerns, and to probe the past and present to re-imagine the future [22]. To do this, the probe pack was designed to bring Phase 1 emergent themes (primarily from HCI/design) into conversation with key concepts from skin studies (a subfield of body studies which brings the body's surface into focus). Skin studies are informed by a transdisciplinary approach drawing on a social science and humanities perspectives as well as critical race studies, gender and sexuality studies, and sensory studies [40]. Both these perspectives, albeit differently, engage with skin in terms of its temperature and durability, its many felt properties (e.g., soft, reactive, hard, conductive, stretchy, thin, thick and layered) and its malleable, adaptable and flexible character. The rich vocabulary of the skin and five critical concepts from skin studies (introduced below) provided potential points of connection with interactive skin research (based in HCI).

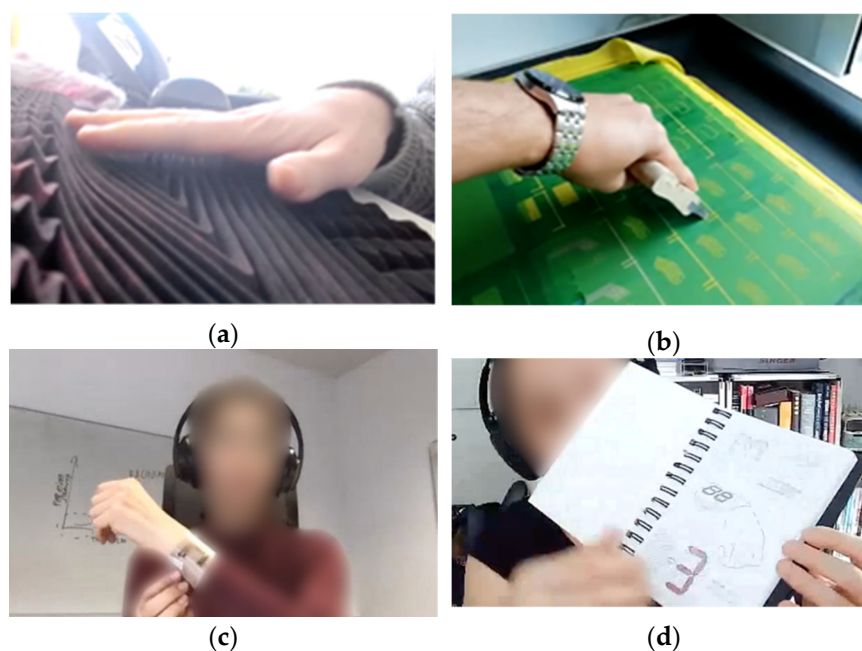


Figure 1. (a) Top left: P5 stroking a fabric they are working with. (b) Top right: P3 demonstrating manual fabrication methods on the lab tour. (c) Bottom left: P8 wrapping an interactive skin device around their wrist. (d) Bottom right: P4 showing her design sketches.

3.3.1. Five Critical Bridging Concepts

Skin as a boundary: Skin studies ask how the skin is conceptualised and what social meanings this achieves. Thinking of the skin as a boundary is seen as a central construction of the skin/body: the skin is 'the ultimate boundary organ ... a cultural border between self and world ... where subjects can encounter each other' [41]. From this perspective, the skin is an 'ecology' through which the notion of, and relations with the self, other and society are shaped [40]. The skin as a boundary and its breaking are also understood

as underpinning skin practices (e.g., tattooing and piercing) and fantasies of penetrating or removing the skin. Skin studies seek to critically rethink the skin to breakdown the conceptualisation of the skin as inside/outside, surface/depth and self/other [42]. These notions of skin as a boundary speak to the place of interactive skin at the interface of the body and technology.

Skin as living, fluid and in flux: Skin studies and interactive skin research both engage with the skin as a living and changing organ. LaFrance argues that the skin is both permanent and temporary, delicate and resilient and is ‘... always already in flux. It is a fluid boundary and a leaky interface. It is configured and reconfigured through affective relations, sensory transactions and social interactions’ [40]. This concept connects interactive skin design’s consideration of the biological and physical processes of the skin in relation to environmental change, with skin studies’ exploration of the experiential, social and biological ever-changing dynamics of skin.

Augment, modify, hack the skin: The practices of modification, augmentation and hacking offer a connection between interactive skin research and design practices, and skin studies’ interest in skin practices (e.g., implants and cosmetic surgery). Skin studies explore the relationship between the skin, body and technology and argue that as technology enables us to modify our skins more than ever, to ‘cross skins, merging with other bodies or colonizing multiple bodies’ [43], the skin is increasingly bound by a collective sociotechnical imaginary that modifies the surfaces of our bodies in transformative ways. The study participants and interactive skin more generally engage with the concepts of augmentation and hacking through a focus on body adornment and tattoos.

Skinscape and skin markers: The concept of ‘skinscape’ refers to the ‘contiguity or intimate association between the surface of the body and the surface of the earth or landscape’ [44]. This conceptualisation of the skin beyond the individual reconfigures the skin as social, an interface and as ‘knowledgeable or sentient’ [44]. Here, the skin is understood as ‘an archive of past experiences, a cartography of identity’ [40], our social and personal histories made visible by ‘skin markers’ from everyday pain (e.g., blisters and scars [43]), intimate experiences, to our ‘public raced, sexed and national histories’ [42]. These concepts connect with interactive skin research/design through questions of how it might connect a wearer to another person or the environment, augment the skin as a social interface, draw knowledge from the skin, store (archive) data or make a wearer’s emotions newly visible or felt.

Skin as a project: The term skin projects (e.g., grooming, bleaching, tattooing, and cosmetic ‘plastic’ surgery [40]) is an extension of how people attend to their bodies as projects in ways that both reflect and reproduce sociocultural structures [45]. This concept points to how the body’s surface embodies tensions in consumer culture and how the visual displays and appearance of skin work to sell a process or the ‘commodification of skin’ [46]. Interactive skin can be understood as a digital skin project.

These five critical bridging concepts offered points of connection between the social, sensory and technological aspects of interactive/skin.

3.3.2. The Interactive Skin Probe Pack

The interactive skin probe pack sought to attune participants to the social and sensory aspects of skin and its remediation via interactive skin technologies. Phase 1 insights and the critical skin study concepts (outlined above) provided a creative springboard for the design of seven probes. The probe names are listed below and mapped to the critical skin study concepts in Table 1.

Table 1. Mapping of the four critical concepts to the interactive skin probes.

Critical Concepts	Probes										
	1a	1b	1c	1d	1e	2	3	4	5	6	7
Skin as a boundary	X		X	X	X						X
Skin as living, in flux			X	X	X		X	X			
Augment, modify, hack					X	X					
Skinscape, markers	X	X	X	X	X		X		X		
Skin as a project		X	X	X	X						X

Probe 1: Skin Attunement (a series of daily activities 1a–e). Probe 2: Hack a Skin Sensation. Probe 3: Make a ‘Tactile Inventory’ of Skin. Probe 4: Living Skin. Probe 5: Skin Landscapes. Probe 6: Boundaries. Probe 7: Skin Postcards.


Each probe features a short creative task that invited participants to engage with and reflect on the skin alongside an evocative image (see Figure 2). The probes were designed to be provocative, playful, open-ended and ambiguous, and enjoyable to complete. Some probes included exploratory experiential tasks focused on doing and describing; these included instructions of how or what to touch, and invited participants to generate a critical reflective response. Probe 2, Hack a Skin Sensation, for example, invited participants to ‘Choose a daily routine when you touch your or another’s skin: human, animal, plant ... Use/imagine using an unexpected object(s) to ‘hack’ a skin sensation; and use micro gestures to act out this ‘hack’’. Other probes consisted of questions to respond to, for example, Probe 6, Boundaries, asked participants to ‘Draw the boundaries of your skin: Are they permeable to outside influences?’ Others suggested tactile sensations to experience, or concepts or images to respond to. Probe 4, Living Skin, for example, included an image of the skin and invited participants to ‘Script a 5-min conversation ‘Between you and your skin’: what does your skin tell you? Listen. Look. Feel.’ The format of the probe responses varied with optional forms including short videos, written notes, narratives, audio notes, sketches or photographs. These formats also drew on the participants’ preferred or specialist practices identified during phase 1 (e.g., enacting micro gestures and sketching).

The probe pack was ‘launched’ in an (online) meeting with participants as a group. A short presentation explained the use of probes, what to expect and the time commitment. Participants were invited to take an informal approach to the materials, and it was emphasised that there was no right or wrong response. The launch included time for questions and answers. The probe pack was emailed to participants following the launch meeting.

All participants were invited to complete Probe 1 and to choose one or two optional probes (from Probes 2–7) to complete by the end of the week. Probe 1 (Skin Attunement) consists of a series of five (5 min) daily activities, one emailed to participants daily for two reasons: first, to bring a routine/rhythm to the attunement tasks as a daily practice designed to encounter skin/touch differently through everyday experiences; second, to provide a sense of surprise to elicit creative responses and avoid participants overthinking the probes. Probe 1 provided participants a collective experience of attunement to the skin. Probe returns were returned to the researchers and participants were asked to share only what they were comfortable with sharing. Participants reported sharing some of their probe experiences and responses with some of the other participants. The probes thus prompted new conversations between participants and researchers and among the participants.

Most participants completed the probe tasks as requested (see Table 2); however, P1 did not complete all Probe 1 daily tasks and P5 returned only one probe due to illness and workload (they participated in the other activities). Optional Probe 5: Skin Landscapes and Probe 7: Skin Postcards were not selected by any participant (on reflection, the latter at 25 min was perhaps too long).

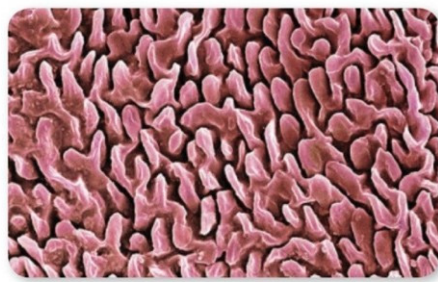
Probe 2: Hack a Skin Sensation
 This Probe will take 5 - 10 minutes to complete
 Choose a daily routine when you touch your or another's skin: human, animal, plant...
 Use/imagine using an unexpected object(s) to 'hack' a skin sensation
 Use micro gestures to act out this 'hack'



Choose a medium from the list below to capture the experience:

- Make a 30-60 second video
- Sketch the experience
- Photo series


Script a 5-minute conversation 'Between you and your skin': what does your skin tell you? Listen. Look. Feel.



Capture the conversation using one of the mediums below:

- Up to 60 second audio recording
- Short written diary entry from the point of view of your skin
- A 3-4 frame storyboard/comic strip
- 1 page draft script


This Probe will take 10 - 15 minutes to complete
 Explore your environment (indoors/outdoors) to find 3-7 textures that you associate with skin to make a mini 'tactile skin inventory'



Mix and match mediums from the list below:

- A series of 5-10 second videos
- Make a list words (from any language)
- Sketch
- Photo

This Probe will take 15 minutes to complete
 Draw the boundaries of your skin: Are they permeable to outside influences?



Press and move 3-5 objects across your skin. Detach them. How do the layers and surface of your skin respond? Are any traces/marks left on your skin?

Figure 2. Top-left: Probe 2; Top-right: Probe 3; Bottom-left: Probe 4; Bottom-right: Probe 6 illustrate the format and tone of the probe pack.

Table 2. The probes completed by the participants.

Participants	Probes										
	1a	1b	1c	1d	1e	2	3	4	5	6	7
P1			X		X		X				
P2	X	X	X	X	X	X					
P3	X	X	X	X	X		X				
P4	X	X	X	X	X	X	X				
P5	X										
P6	X	X	X	X	X	X		X			
P7	X	X	X	X	X			X		X	
P8	X	X	X	X	X						X

3.3.3. Discussion Phase 2

Phase 2 provided participants with a novel space for creative, felt explorations attuned to (interactive) skin. The participants (in exit interviews) described the probes as “exciting” “open”, “fun”, “enjoyable” and “interesting” and that the probes enabled a new attunement to the skin:

“During our conversations, there were some points that came out which were implicitly present. Like my work is relative to skin ethnicity, but I didn’t notice it

in that way . . . I think that the probes somehow expanded my horizons to think about skin parts . . . Everything combined together to help me think". (P2)

"When I go on vacation I might write some postcards to my skin". (P4)

The probes brought forth strong felt memories of the skin, themes of comfort (e.g., self-calming), protection, and fear (e.g., in relation to COVID-19), confirming the need to consider the ethics of probes including how they are shared. Participants commented that the probes helped to expand their notions of the skin (and touch) from a design focus on the hand/arm to the whole body and, in doing so, newly drew their attention to barriers to the skin (e.g., clothes). The probes helped to newly foster reflection on the changing character and boundaries of the skin, its textures and how this map to practices of care and body 'maintenance' (e.g., moisturising). They also highlighted the political, social and sensory aspects of skin experiences that they found useful. Participant comments also drew attention to their emotional and felt connection through the skin with the self, others (friends and family) objects and environments (e.g., the sun and the seasons). Several participants expressed surprise in how touching something familiar newly could reveal information or evoke memories to bring the contours of the skin newly into view. Collectively, the probe method encouraged participant exploration and engaged them with the social aspects of skin in unexpected and interesting ways. In response to Probe 5, for example, a participant (P6) improvised a script which he performed with a friend and video recorded.

The above themes (together with insights from Phase 1) were used to ground the speculative work of Phase 3 in participants' interests in and sociotechnical imaginaries of interactive skin. More generally, the playful creative space generated through engagement with the probes provided an entry point into the work of speculating on the social/sensory aspects of (interactive) skin and exploration of the relationship between body and technology in Phase 3.

3.4. Phase 3: Speculating

Phase 3 explored the futures of interactive skin through a speculative design workshop and a closing interview. The workshop activities were designed to foster collaborative conversation between the participants and the case study researchers and to explore their sociotechnical imaginaries of interactive skin, support engagement with critical socially orientated concepts of skin, and to map the possibilities and challenges for interactive skin futures. The workshop was inspired by a speculative conference presentation [47] (attended by one of the authors) on shape-changing interfaces in which the audience were invited to 'Close your eyes. Imagine you are in 2068 . . . Shape changing interfaces are here!'. The presenters asked 'How did we get here?' and counted back from 2068 to mark the landmarks that had shaped the future. When their narrative reached the present-day—then 2018—the presenters asked, 'Too utopian?' and reversed tack to moving rapidly forward to 2068 to offer a more dystopian vision of shape-changing interfaces futures, and pointing to other futures that might play out between these utopic and dystopic extremes.

The interactive skin speculative workshop filtered participants' research and design knowledge of interactive skin (gained through Phases 1 and 2) through a 50 year 'futures timeframe' to project interactive skin from 2021 to 2071. This timeframe and five starting points for the future projection were used to create a table on Miro, an online collaborative platform familiar to the participants. The five starting points reflected the distinct disciplinary focus or area of research interest expressed by participants (in Phase 1) (i.e., technological and material development; design usability and awareness; physiological and sensory; user interaction behaviour; societal impact, norms and regulation). Miro was used to support, share and capture participants' responses to workshop activities. The workshop (2.5 h) consisted of two activities centred on the table followed by a group brainstorm and discussion of the social issues for interactive skin futures. During the workshop, we (authors 1 and 2) immersed in the social, sensory, and technical possibilities

of interactive skin (through Phases 1 and 2), positioned ourselves as participant-facilitators and contributed to the discussions from our socially orientated perspectives.

Activity one (1 h) was grounded in a future technological starting point (a shared point of connection for participants) and invited participants to: ‘Imagine it is 2071. Interactive skin interfaces have happened: they are ubiquitous. People love them! How did we get there? Four years ago, in 2067 a large technology company developed ‘PureSkin’—a detachable, reliably conductive and digitally sophisticated wireless skin interface, which is invisible to the human eye, contours to any location on the body, and is so thin that it is barely perceptible through touch’.

The Miro table dimensions were introduced. Participants were invited to select one or more starting points and to use Miro sticky notes to follow that trajectory through time to speculate on and plot the future(s) of interactive skin. Participants worked individually and simultaneously, and our identity (represented by an icon and colour coded stickies) was visible to one another as we worked on the board. As the table was populated, participants started to interact with (e.g., build on or react against) one another’s sticky-note comments and projections. Through this process, a dynamic multifaceted collective mapping of interactive skin futures was generated (Figure 3)



Figure 3. Miro board collective mapping of interactive skin futures.

Activity two (1 h): while activity 1 brought some attention to the social, this activity sought to foreground and track how the social might manifest to disrupt, probe and stretch the futures of interactive skin and invited participants to: ‘Imagine it is 2071. The design, fabrication and use of various forms of interactive skin are ubiquitous and are being experimented with in unanticipated ways and with unintended consequences. Governments, corporations and new communities are all actively engaged in the use and monitoring the use of interactive skins. In short, interactive skin is out of the control of designers, engineers’ [i.e., out to the control of the participants].

A set of 10 ‘disruptor probes’ were introduced to the Miro board. Each probe was built around an emerging theme (from Phases 1 and 2) and consisted of two elements—first, a short social and sensory attuning activity (a movement, feeling or material), and second, a speculative provocation (Figure 4). For example, Longevity of interactive skin: *Remember your skin in years past. How soft are your hands—how different your complexion?* As the common phrase now goes, ‘aging is no longer skin deep’; or Skin boundaries: *Interlock your fingers.*

Squint so it is hard to discriminate the two surfaces—through sight or feel. Now find an object close by a close in colour, texture and temperature to your skin. Squint again: The materials and methods of interactive skin have become so advanced that people are complaining that they have lost where they end, and their second skin begins.

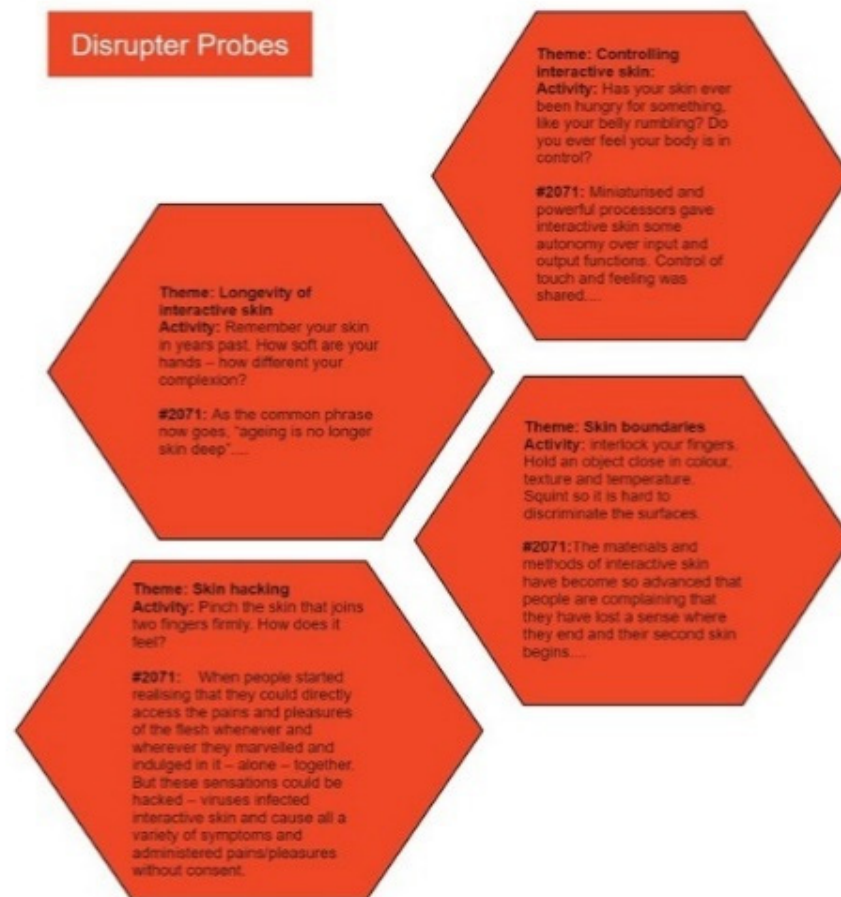


Figure 4. Examples of Disrupter Probes ‘dropped’ on the grid-board.

The task of responding to the Disrupter Probes was introduced to participants: ‘The future is uncertain: disruptions and unexpected events and developments rain down in the form of ‘Disrupter Probes’ set to crash into the interactive skin futures you have plotted. Working as an Interactive Skin Rapid Response Team, you need to track their scattering effect across the plotted timeline: discuss, add new stickies, extend or adapt existing stickies’.

As each Disrupter Probe landed onto the board (in a specific time period), participants were required to work collectively to review the board and react. Several of the Disrupter Probes triggered participants’ use of the ‘proxy feeler’ method (demonstrate, feel and disrupt). As the *Skin boundaries* Disruptive Probe dropped onto the board, for example, a participant began to act out the attuning exercise-‘*Interlock your fingers. Squint so it is hard to discriminate the two surfaces—through sight or feel. Now find an object close by a close in colour, texture and temperature to your skin. Squint again*’ and the other participants joined in with this action (Figure 5). This prompted a discussion of the materials and the boundaries of the skin and interactive skin.



Figure 5. Screenshot of participants using the ‘proxy feeler’ method with the Skin boundaries Disruptive Probe.

Participants’ use of the Disrupter Probes led to socially orientated reflection and discussion, sedimented in an overlay of reflective stickies.

“I think that was good it showed us very interesting aspects, taking some desirable or undesirable futures, and then designing backwards from them . . . we lack an approach or method of working against those things that are not desirable . . . this is a practical way to engage engineers to take concrete steps to go somewhere or in this case avoid undesirable futures”. (P1)

The third and final brainstorming activity (30 min) reviewed the map generated through the previous activities to explore the social challenges and possibilities for interactive skin futures. This provided an opportunity to select and refine themes exposed through the speculative workshop process, conversations that continued with participants in an exit interview to explore further what resonated with their work or agitated their thinking.

3.4.1. Exit Interview

A closing interview was conducted with each participant (online and between 30 and 45 min long). These interviews focused on eliciting participants experience of bringing the social to the fore of interactive skin, and the case study methods including exploration of if and how engaging with this approach had contributed to their design/thinking. The interview closed with participants’ Probes 1e, which asked participants to, ‘*Reflect on the Probes you have done this week and write a new set of instructions for another person to attune to the skin*’. The participant introduced the probe, the interviewer undertook the task and shared their response.

3.4.2. Discussion Phase 3

Participants enjoyed the workshop and found it useful:

“The speculative session worked super well, we identified a lot of material, we could write a paper on speculating what are the challenges for skin interfaces . . . the workshop after a creative boost this worked well, I think I am going to read this method.” (P6)

The workshop Miro boards were transcribed and collated to produce a series of bullet points for each time period. That was shared with the lab leader to review, comment on and rank (high–medium–low) in relation to their significance for the future of interactive skin. This underpins the development of a speculative narrative on interactive skin aimed at supporting reflection and questioning, and disrupting and extending the work engineers, designers and researchers working with interactive skin (Jewitt, Barker and Steimle, forthcoming). The narrative brings the five starting points of the workshop mapping exercise (i.e., the technological, material, design, physiological, user interaction behaviour, sensory and societal) into a 50-year temporal framing and puts them into synergetic conversation to expose the tensions and connections involved in the future of this emergent technology.

In addition, the workshop and exit interviews generated a rich collection of themes. How social practices shape our touch interaction with technology was discussed, for example, how manual practices alter skin and technology interactions (e.g., one participant noted how using a sander for extended periods resulted in his fingerprints not being recognised by his phone). The balance of beauty aesthetics vs. the functionality of interactive skin and the notion of what beautiful skin looks and feels like raised questions around the place of culture and skin. A discussion of skin longevity explored how the skin is living and future possibilities of digital skin protection (e.g., from pollutants) or having ‘younger patches’ of interactive skin were raised, alongside evolving health-care skin behaviours being altered through interactive skin (e.g., skin masking for skin tone and ageing). Participants discussed how this might reinforce or eliminate existing class, culture, racial and disability inequalities realised at least in part through the skin. The concept of body-schemas and how interactive skin may become part of or disrupt them wove across the workshop mapping. The social consequences of ‘hacking’ interactive skin devices, and specifically the close connection of these devices on the body might result in losing trust in one’s own body was explored through discussion of privacy and security (who would have access to the device?)—raising ethical questions of control and surveillance. The complex boundaries between the ‘living’ and ‘non-living’ with and within (e.g., mitochondria) our bodies led to discussion of ethics around ‘skin boarders’ as well as the potential risks of prolonged wearing of interactive skin, or the symbiosis between interactive and natural skin: ultimately raising questions of how to control technological and bodily integration. Collectively, these themes and their discussion raised socially focused questions and challenges, revealed and critically explored participants’ expectations and assumptions of interactive skin and ultimately unsettled dominant technological visions. They also highlight how creative research methods can be used, such as in this study, to explore the relationship between body and technology.

4. Discussion

The novel approach described above is critically discussed in relation to the opportunities, challenges and limitations it presented in this case study and, more generally, the use of creative research methods for exploring the relationship between body and technology.

4.1. Opportunities and Contributions

Collaborative interdisciplinary sensory/social attuning: Each phase of the approach provided participants and researchers with a cumulative reflective scaffold that activated their bodies through subtle interactions towards a fresh engagement with the social critique of interactive skin as an emergent technology. Phase 1 enabled a thematic analysis to identify routes to be developed (and diverted) towards a social understanding of interactive skin in Phase 2. The probing afforded by Phase 2 identified conceptual points of connection to bridge participants’ HCI/design understanding of interactive skin with those of skin studies to develop a collaborative interdisciplinary attuning.

Facilitating dialogue: Combining creative and social research methods facilitated research dialogue between the social science and HCI/CS researchers and designers by enabling us to blend researcher-positions, share and explore vocabularies, and foreground

aspects significant for the research and design of interactive skin. In turn, this lay foundational pillars on which to co-create collaborative futures for emergent technologies—here interactive skin. Demystifying and bridging different perspectives on interactive skin (e.g., social, physiological, technological, material, and design) helped to identify new pathways to the social and sensorial. Making explicit the social and sensory was key to this dialogue, notably the design of reflective activities to link participants' sensorial and social experiences helped to expand the design space.

Expanding engagement: While discussion of the social aspects (e.g., social acceptance) was a part of the lab's design of concrete interfaces it was not a key focus – and most participants were engaged with the skin through a technological HCI/design lens, the novel approach described here provoked and supported them to think-through-feeling in ways that expanded their engagement with interactive skin from the technological to the sensory to the social. When discussing the case study aim to feed social and sensory thinking into future design processes, one participant commented our approach had helped him to “Sharpen my perspective or take a different perspective on the problem we are working on” (P1), while another commented “I think that the probes somehow expanded my horizons to think about skin parts” (P2). The approach set out in this paper also prompted participants to think beyond self and direct touch with objects or others to consider interactive skin in relation to proximal touch and environmental touch—extending participants design possibilities beyond the individual to the connected collective.

Generating themes: While the focus of this paper is methodological, the approach generated many themes, categorised into a set of four interconnected high-level themes central to participants' discourses and imaginaries of interactive skin: sociality of interactive skin, sensorial experiences of interactive skin, ethics of interactive skin and the materiality of interactive skin; and three cross-cutting themes—body location, boundaries and temporality, were developed. Given the emergent character of interactive skin, these themes remain in process, not yet fully formed, open to contestation and resistance. Nonetheless, they are an analytical resource/tool to flesh out the challenges that encompass the future of interactive skin and to move critically across the overlapping social, experiential, ethical and materiality of interactive skin.

Shaping research practice: The novel approach impacted on the researchers' practice by opening an opportunity to take the speculative register and collaborative/participatory character of the workshop forward in the form of a collective narrative filtered through five disciplinary starting points and a 50-year timeframe to consider the futures of interactive skin. This is just one direction opened by the novel approach described in this paper. The above contributions show how bringing HCI, creative and social methods and concepts into conversation can expand the design space of interactive skin and other emergent technologies in the domain of HCI. This approach extends a mainstream user-centred design approach through attention to the sensory and the social through creative, reflective and empathetic methods of attuning to one's own experiences distinguishes to better understand and critique the social and sensory implications and potentials of interactive skin, and its relationship to touch. This is important in the context of interactive skin as its closeness to the human skin raises significant questions including for ethics, privacy and security, and social norms.

4.2. Challenges and Limitations

Managing positionalities: A set of dynamic tensions manifested between researcher and participant positional relations and purposes. While many of these were productive in facilitating dialogue and stretching research practices, others required cautious navigation. First, the use of online platforms made the case study researchers hyper-visible on participants screens and heightened the challenge of negotiating researcher-participant positionalities. We sought to remedy this tension through increased attention to rapport building (e.g., follow-up email conversations, sharing readings or inspirations), and by gradually repositioning ourselves through speculative workshop (and engagement with

Probe 1e in the exit interviews) towards becoming co-participants. However, our virtual presence left us more 'on the outside' than perhaps a physical research encounter would have. Second, by exploring participants' methods, concepts, and approaches to the design of interactive skin, the differences between lab members were brought to the surface. In doing so, tensions *between participants'* positionalities were exposed; again, these tensions were largely productive in this case study as they led to new ways of thinking, feeling, and talking about the sociality of interactive skin. However, such tensions need to be navigated in ways that were sensitive to the team's dynamic. Third, tensions arose through the probing nature of the collaboration because this challenged established identities and practices researchers and participants have formed through their background and training. In general, the approach was considered as exciting and expanding, but one of our challenges was to notice and manage different identity positions as they surfaced but also as they shifted.

Risky methods: The openness and ambiguity generated by creative methods can support novel thinking in powerful ways; however, it can also create unease, discomfort or triggering effects, particularly in a group context or when working at the intersection of the body and technologies. Moreover, the act of speculating is risky: to speculate is to take the risk of developing practices (and in this case, technologies) that may have unexpected consequences within uncertain futures [31] and can be challenging for some. Prompted to think and feel possibilities of the future risks of their current design trajectories brought participants' wider concerns about ecology and politics into the conversation. On the one hand, we sought to disrupt and stimulate creative speculative engagements with interactive skin, wherever these may lead, and on the other, we became sensitive to the possible negative effects that such risky explorations may have for participants and sought to limit these. Our challenge was therefore one of balance.

Remote methods: There were two key challenges with conducting this exploratory interdisciplinary case study online. The first was to allow room and opportunities for serendipity and chance encounters/activities when the interaction necessarily occurred through scheduled and planned events. We intentionally incorporated unstructured spaces for discussion (e.g., in interviews), were not overly prescriptive with probes, and continued dialogue through email to establish an asynchronous channel of communication. The second challenge was to navigate the distance created between the researcher and sensory environments/phenomena by not 'being there' [39]. Something akin to shared presence was achieved by affording engagements with the sensory and sociality of interactive skin: "It's not like being there ... but yeah, I think it's been close enough" (P3) and the use of 'proxy feelers'.

Determining analytical processes and value: Conceptual recourse and analytical processes do not always neatly align and analytical tensions emerged throughout the phases regarding which concepts to give primacy to shaping the process and findings. The authors continuously reflected on these choices and our unfolding decisions and discussed the goal of the analytical processes. We handled data, generated themes, and shaped the process with a view to add critical value to the findings with the potential to inform the participants work. Central to this was exploring ways to navigate how to balance the range of disciplinary perspectives that were in play, and bring our critical lens and that of skin studies into the analysis without naively positioning participants in relation to the social and avoiding the trope of the all critical/knowing social scientist. This brings us full circle to the power of this method to facilitate interdisciplinary dialogue and to the value of the collective narrative as a research outcome that creatively combines multiple perspectives to speak back to the study of interactive skin in ways that challenge and expand any single disciplinary mode of thinking.

More general limitations of the study reported in this paper include the study's focus on one lab team, albeit one emblematic of the field and the remote rather than in person character of the study due to COVID-19 restrictions. The latter shaped the methods in particular ways, for example making us reliant on the materials available to

participants (rather than providing materials) and limited our sensory experience of the lab and interactive skin.

5. Conclusions

This paper has argued that, even within the constraints of remote online research, creative methods can be harnessed to attune researchers/participants and ‘stretch’ collaborative and collective design thinking towards the sensory and social present and futures of interactive skin in new to ‘bring the body back in’ and extend user-centred design in new and productive ways. The challenges generated by this approach included managing positionalities, working with risky methods and determining analytical processes and their value. A central value of this approach is that it facilitated collaborative research dialogues between social science and HCI/CS researchers and designers to successfully agitate a technological design space and lay significant collaborative pillars on which to co-create futures for emergent technologies (here, interactive skin). Demystifying and bridging different perspectives on a technology (e.g., social, physiological, technological, material, and design) worked to expand design engagement with the notion of interactive skin, and generated new analytical themes, research questions, and imaginaries of interactive skin across the present, past and future. The approach helped to shape both research practice and outputs. In doing so, this paper makes a case for creative methodological improvisation and exploration of the blurring boundaries between body and technology with attention to how moving across and between creative and social research methods can engage questions significant for technology, society and design.

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