The Senses and Society

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rfss20

Interactive skin through a social- sensory speculative lens

Carey Jewitt, Ned Barker & Jürgen Steimle

To cite this article: Carey Jewitt, Ned Barker & Jürgen Steimle (2022): Interactive skin through a social- sensory speculative lens, The Senses and Society, DOI: 10.1080/17458927.2022.2145840

To link to this article: https://doi.org/10.1080/17458927.2022.2145840

Published online: 24 Nov 2022.

THE SENSES AND SOCIETY
https://doi.org/10.1080/17458927.2022.2145840

Routledge
Taylor & Francis Group

Interactive skin through a social- sensory speculative lens

Carey Jewitt[a], Ned Barker[a] and Jürgen Steimle[b]

[a]UCL Knowledge Lab, Dept. Culture, Communication and Media, IOE, University College London, UK, London; [b]Computer Science, Saarland University: Universitat Des Saarlandes, Saarbrücken, Germany

ABSTRACT

This paper uses a speculative lens to explore the social and sensory trajectories of Interactive Skin, a class of skin-worn epidermal devices that augment the human body in ways that are significant for affective techno-touch. The paper presents and discusses the use of a speculative narrative on Interactive Skin futures produced through an exploratory research-collaboration with a Human–Computer Interaction (HCI) lab, combining data from speculative methods (cultural probe returns and a future-orientated workshop) with an ethnographic sensitivity to writing. The speculative narrative is in the form of a found archive of fictional fragments that are research provocations in their own right. We discuss their potentials, including the ability to foster interdisciplinary dialogue between social and HCI researchers and to agitate the socio-technological space of interactive skin futures, as well as their limitations. The paper concludes that a socially orientated speculative approach can provide useful insights on the interconnection between the senses, society, and technology in the context of emergent affective techno-touch technologies.

KEYWORDS

Skin studies; touch; interactive skin; Human-Computer interaction; social research; speculative research methods; ethnographic writing; wearable computing

Introduction

Interactive Skin is an emerging class of affective touch technology, on-skin user interfaces, and devices that directly augment and/or interact with the human skin at the blurry intersection of technology and the interface of the body. This paper argues for the consideration of social and sensory, material and ethical trajectories of Interactive Skin technologies, and proposes a socially orientated speculative approach as an interdisciplinary route to support this. The paper centers on a speculative narrative on Interactive Skin futures in the form of a "found archive" of fictional fragments including a research journal-note, an e-mail exchange, and an advert. These are research artifacts generated through an exploratory research-collaboration with HCI researchers that combined the use of creative methods (see Jewitt, Barker, and Golmohammadi 2022), core concepts within skin studies, and ethnographic writing practices (Atkinson 2015) with speculative methods. Three archive fragments are presented as a "troubling resource" (Galloway and Caudwell 2018) to highlight participant-collaborators' discourses and imaginaries of interactive skin organized around four themes: sensorial experiences, sociality, materiality, and ethics.

CONTACT Carey Jewitt c.jewitt@ucl.ac.uk

The paper discusses the potential and limitations of the archive fragments and a socially orientated speculative approach more generally. It concludes that this approach can foster interdisciplinary dialogue between social/sensory and HCI concerns in ways that agitate the socio-technological space of interactive skin futures and contribute to the work of navigating the future of affective techno-touch.

Background

Advances in HCI, new materials, electronics, sensor design, and fabrication have led to the emergence of electronic devices that reside directly on the user's skin (Weigel et al. 2015; Steimle 2016). Interactive skin is an emerging class of skin-worn epidermal devices (i.e. noninvasive). In contrast to classical wearable devices, their very small and thin (thinner than a human hair) form factor, their biocompatibility and their elastic deformability tailored to the human body enables them to better augment and integrate into human skin. They can continuously monitor physiological parameters (Nittala et al., 2019) and act as a display, both visual (Kao et al. 2016; Weigel et al. 2017) and haptic (Withana, Groeger, and Steimle 2018). While many technologies (from the walking stick or cane, to the smartphone) mediate people's lives and bodies in various ways, interactive skin significantly blurs the boundary between human and technology and takes a more active role. Interactive skin feels and behaves like parts of the body going beyond the interaction between users and devices to what Mueller (2020) consider a new paradigm of Human Computer Integration in which computational and human systems (i.e. the body) are more closely interwoven. Such an integration occurs primarily at an individual level through sensory fusion, with computers providing information directly to human senses rather than through symbolic representations and understanding the user's implicit needs through bio-sensing.

We draw on a speculative lens and concepts from skin studies – a subfield of body studies that brings the body's surface into focus from a transdisciplinary approach (Lafrance 2018), as entry points into the design futures of Interactive Skin .

Socially orientated speculation

The discursive space of Interactive Skin (and many other emergent affective techno-touch technologies) unsettles the boundary/interface between the body and technology. Such unsettled spaces underpin calls for "lively" social research methods (Vannini 2015). The retuning of social research in response to a general dissatisfaction with the limits of social research methods (Mason and Davies 2009), turns to the multimodal (Jewitt, Bezemer, and O'Halloran 2016) or multisensory (Howes and Classen 2014) make social research fertile terrain for a speculative register (Savransky, Wilkie, and Rosengarten, 2019).

Speculative design practice provokes contemplation, examines values, and fosters collective reflection through making (Dunne and Raby 2013). Speculative design is concerned with generating insights on the future or near-future design possibilities to act as catalysts for the kinds of futures people want, including the role technology plays or might play in our lives (Auger 2013), and thus engages us in newly understanding our present moment (Mitrović 2019). Speculative methods are considered in terms of a disposition (rather than a method) characterized as questioning, ambiguous, open,

provocative, challenging, and concerned with knowledge of emerging trends, technologies, and behavior (Hanna 2020). A process that requires "thought to become felt, fact to become potential, imagination to supersede observation" (Parisi 2012, 241) and which becomes a driver for new social realities. A speculative perspective understands futures as multiple, spanning from the potential to the preposterous, plausible, possible, probable, preferable, or projected. Futures are thus always on the move rather than one-fixed point, and a force on the present. This means keeping alternative voices and considerations alive and in tension (Bell et al. 2013) is key in order to create speculative discursive spaces (Mitrović 2019).

Speculative research narratives have been described as a form of "social science thinking" and "a methodology for grasping the social" (Gerlach and Hamilton 2003, 168). Social researchers have used this approach to explore the potentials of new technologies (e.g. Blythe 2014), emerging and uncertain worlds (e.g. Salazar et al. 2017), and to craft critical social science fictions on digital education (e.g. Ross 2017; Selwyn et al. 2020). Socially orientated speculative narratives vary in genre, including short stories, films, vignettes, or as in this paper, a "found archive." Important considerations in writing such narratives include the need to balance technological and social elements to avoid focusing on technological-gadgetry and to maintain its critical value and ability to provoke (Bell et al. 2013); engaging with future social and ethical implications (Gorjanc 2019); and denaturalizing familiar practices to re-imagine "counterfactual lines of development" to ensure the narrative illustrates how the present could be organized differently (Davison-Vecchione and Seeger 2021, 18).

A speculative lens drawing on skin studies

Within a socially orientated speculative approach, we draw on the concepts of skin studies outlined below to develop critical points of connection between skin studies and HCI Interactive Skin research.

The boundary of the skin, references how the skin is conceptualized and the social meanings this achieves speaks to the place of Interactive Skin at the interface of the body and technology. Thinking of the skin as a boundary, the ultimate boundary organ, "a cultural border between self and world" is central to the construction of the body (Benthien 2002). The skin is thus an "ecology" through which the notion of and relations with the self, other, and society are shaped (Lafrance 2018). The breaking of the skin underpins many skin practices (e.g. tattooing, piercing). Skin studies and Interactive Skin both seek, albeit differently, to critically rethink the skin and to breakdown the conceptualization of the skin as inside/outside, surface/depth and self/other (Ahmed and Stacey 2001). As we will discuss, the question of the boundaries between skin and technology is key within Interactive Skin design and its futures.

Conceptualizing the skin as living, fluid, and in flux, a living and changing organ, is significant for both skin studies and Interactive skin research. The skin is both permanent and temporary, delicate, and resilient and is " . . . always already in flux . . . configured and reconfigured through affective relations, sensory transactions and social interactions" (Lafrance 2018, 6). Conceptually this connects skin studies exploration of the experiential, social, and biological ever-changing dynamics of skin with the design considerations of Interactive Skin with respect to the biological and physical processes of the skin in relation

to environmental change (Aditya et al. 2019). This includes understanding how epidermal devices affect skin functions (e.g. body movement, thermal management) and the effects of their long-term use (e.g. deterioration).

Modification, augmentation, and hacking are practices discussed within skin studies in relation to skin-practices (e.g. implants, cosmetic surgery) and the social relationship between the skin, body, and technology. Some argue that technological skin modifications enable us to "cross skins, merging with other bodies or colonizing multiple bodies" (Flanagan and Booth 2007, 1). The participant-collaborators in this study, and those working with interactive skin more generally, also engage with augmentation and hacking (e.g. body adornment and tattoos) as design inspirations.

Skin-scape refers to the "contiguity or intimate association between the surface of the body and the surface of the earth or landscape" (Howes 2018). This reconceptualizes the skin beyond the individual, as a "knowledgeable or sentient" social interface in which the skin becomes 'an archive of past experiences, a cartography of identity" (Lafrance 2018). Our social and personal histories are made visible by "skin markers" from everyday pain (e.g. blisters and scars) (Flanagan and Booth 2007), intimate experiences, to our public raced, sexed, and national histories (Ahmed and Stacey 2001). In addition, the skin's contact with the world is mediated by technologies in various ways, notably clothing. Ciaunica et al. (2021) refer to the clothes and materials that closely envelop the skin and mediate tactile experiences as "extended skin" or "second skin," and propose that the skin and tactile experiences "distinguish and connect the bodily self to its environment" … rather than being "a border separating the self and world." The question of how the relationship between the skin, the self and the world are mediated as well as where (and how porously) one draws the boundaries between them, is a matter of considerable political, ethical, disciplinary, and methodological debate. This resonates with how Interactive Skin might serve as a social interface to connect wearers to another person or the environment, draw knowledge from the skin or make emotions newly visible/felt – issues raised by the study participants and incorporated into the fictional fragments at the heart of this paper.

Skin projects (e.g. grooming, bleaching) (Lafrance 2018) is an extension of how people attend to their bodies as projects in ways that reflect and reproduce sociocultural structures. This concept points to how the body's surface embodies tensions in consumer culture and the "commodification of skin" (Borgerson and Schroeder 2018). Interactive Skin can itself be understood as an emerging technological skin project.

The above concepts were filtered through a speculative approach to inform the research method and development of the speculative narrative presented in this paper.

Method

The study aimed to better understand the social and sensory implications and potentials of interactive skin in order to inform its future design. It brought skin studies into a new dialogue with the HCI design space of interactive skin to provoke and support thinking-through-feeling that expanded from the technological to the sensory and the social. This was achieved by combining speculative methods with a socially orientated creative approach (see, Jewitt, Barker, and Golmohammadi 2022). The study was a collaboration with an HCI lab comprised of researchers with backgrounds in computer science, HCI,

design, and engineering. The lab was selected as a central node in the international field of Interactive Skin. It was recruited via an initial meeting with the lab-leader followed by an invitation to the lab members working on interactive skin to participate. An information sheet and a consent form were sent prior to the start of the study and a process of informed consent was undertaken, participation was voluntary. All (eight) lab members working on interactive skin agreed to participate.

The study was conducted remotely (online, due to Covid-19 travel restrictions) and had three phases. Phase 1 consisted of a literature review, a lab tour by a member of the lab via a mobile phone online video call, and in-depth (45–60 mins) sensory research interviews with each team member. Sensory interviews explicitly bring a range of embodied experiences into the conversation by emphasizing and inviting engagement in, and reflection on, multiple sensory ways of knowing through a pool of established techniques (Barker and Jewitt 2023). Techniques include conducting the interview whilst doing activities to emphasize the embodied nature of the encounter, using objects during interviews (Harris and Guillemin 2012; Thorpe et al. 2022) to emphasize the materiality of the encounter or as prompts for discussion to stimulating participant reflection on their touch experiences (Jewitt et al. 2021; Price et al. 2021). These methods were used to explore participant-collaborators' working concepts and methods and the social and sensory trajectories of their current designs, lines of research. In Phase 2, we used a reflexive thematic analysis Braun and Clarke 2019) of the Phase 1 encounters. This involved familiarizing ourselves with the data, generating descriptive codes, constructing themes, and collaboratively reviewing potential themes and iteratively defining and naming themes. The organic, flexible, and iterative character of this approach was appropriate to the exploratory character of the study. We combined the thematic analysis with concepts from Skin studies and a speculative disposition (see background) to provide a creative springboard for the design of a pack of seven cultural probes (Golmohammadi 2022). Figure 1 shows four of the probes to illustrate the format and tone of the probe pack.

Participant-collaborators were introduced to a speculative and cultural probe approach prior to receiving the probe pack. They were asked to complete a daily probe task (for five days) and to complete one to two optional probes over the week. In Phase 3, we designed and facilitated a half-day speculative design workshop to explore the emerging themes from Phases 1 and 2. Inspired by Alexander et al. (2018), we asked participant-collaborators to "*Imagine it is 2071. Interactive skin interfaces have happened: they are ubiquitous. People love them! How did we get here?*." The discussion was recorded using sticky notes and annotations on Miro (an online collaborative platform familiar to participant-collaborators) and researcher fieldnotes. Participant-collaborators built on and reacted to one another's comments using sticky notes. The resulting multi-layered Miro board represented the synergies, common threads/themes, points of connection and differences across the group. The board was transposed into a list of bullet points organized on a 50-year time line. Closing interviews (30 mins) were conducted with participant-collaborators within Phase 3. Unfortunately, due to word length, it is not possible to present details of the research outputs from phases 1–3 to illuminate participants commentaries; however, these are reported in more detail elsewhere (Jewitt, Barker, and Golmohammadi 2022).

Data analysis generated four interconnected themes central to participant-collaborators' discourses and imaginaries of interactive skin set out below.

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

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

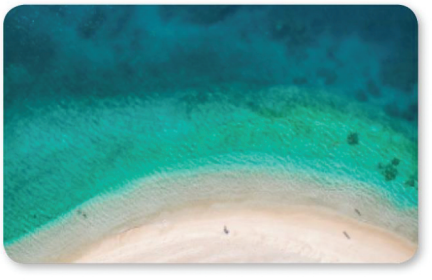
Script a 5-minute conversation 'Between you and your skin': what does your skin tell you? Listen. Look. Feel.

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
- I page draft script

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 1. Probes 2, 3, 4 and 6 are pictured to illustrate the probe pack format and tone.

The sensory experiences of Interactive Skin futures, engages with the senses and perception including both physiological and psychological processes of feeling, connection, and presence, memory, the boundaries of the self, and what the skin reveals to the self and others. This theme explores how the skin mediates the perception of materials, objects, others, and the environment, to shape our experiences of the world and the extent to which technology should or could mimic or remake people's sensory worlds.

The materialities of Interactive Skin futures engages with the material properties of the technology (including visibility, textures, temperature, live-ness), the on-body-materiality of the human skin, as well as the relationship between these in terms of compatibilities, integration, and movement. Both skin studies and interactive skin research, albeit differently, engage with skin in terms of its temperature and durability, felt properties (e.g. soft,

reactive, hard, conductive, stretchy, thin, thick, and layered) and malleable, adaptable, and flexible character. This theme brings attention to the two-way exchange between technology-body and how this extends beyond the personal to the social.

The sociality of Interactive Skin futures explored how the existing social-cultural norms associated with the skin are implicitly designed into prototypes, including norms related to gender, age, culture, race, and beauty. Encompassed in this theme are the accepted social practices of self-touching and touching another's skin in types of relationships, and the constraints (e.g. body location) on when and where this is acceptable, taboo, or abusive. This theme foregrounds the need to ensure digital mediation of these norms and practices does not lead to misrecognition, social-conflict, embarrassment, or stigmatization, and the need for a socially critical approach to future interactive skin design.

The ethics of Interactive Skin futures raise a range of questions for the future design and use of this emergent technology. Ethics is prominent in response to the stakes at play including the balance of control and autonomy between the technology/user (e.g. body-location); concerns of privacy, security, and protection against skin hackers; user consent to data and experience sharing; potential harm to the skin or tactile sensation; and questions of sustainability. This theme explores the place of ethics in the design of emergent technologies and the stage at which ethics comes to "matter" in its development, take up, and regulation.

The above analytical themes, while research outputs in their own right, also served as a "resource/tool" to flesh out the challenges that encompass the future of interactive skin and informed the process of speculative writing.

Process speculative writing

The decision to produce a research-output in the form of a speculative narrative was motivated by and aligned with the study's use of creative methods and its ambition to agitate critical interdisciplinary conversations between HCI and social/sensory interests on Interactive Skin.

We combined a speculative approach with the practice and principles of ethnographic writing (Atkinson 2015) to ensure the narrative was grounded in the data and to expand from the technological to the social and sensory by engaging with the contexts of interactive skin design and use. This enabled us to attend to the cultural resources, objects, and physical "stuff" of interactive skin, lab-life, and the broader institutional and social (e.g. commercial/industry) activities and conventions that shape them. It also rooted the speculations in participant-collaborators' sensory and multimodal communication. Overall, the writing process engaged imaginatively with social questions about how people might live with interactive skin, to inform its future design and development.

Our initial intention was to create a coherent speculative narrative of interactive skin futures told across the life-time of one fictional character (e.g. PhD student, user, or technology journalist). We experimented with different genres (e.g. a diary, news article, blog) to tell this character's story. Ultimately, however, we found that the diverse and contradictory voices of the case-study participant-collaborators could not be adequately captured through the voice of one fictional character. We changed strategy and experimented with meta-narrative forms to allow multiple registers and characters. We settled on an archive collection of documents, which we imagined had been kept by the lab lead

and found by a colleague after 2071. The archive supports an eclectic mix of genres and voices including an imagined newspaper article on the rise of Interactive Skin devices; an interview with a leading technologist on new trends; guidelines on the use of Interactive Skin; a lab accident report; a study ethics form; a page from a research journal (Figure 3); an e-mail exchange between colleagues discussing regulation (Figure 4); and an Interactive Skin advert (Figure 5). While each fragment is situated on a projected 50-year future-timeline, the incompleteness of a found archive also offers a way out of a linear chronology and points to multiple futures.

A table was used to root each speculative fragment in the research data. Each table provided a comprehensive set of research-data-content which was woven into each fragment to mobilize the voices and views encountered through the research collaboration. Given the contradictions and conflicting ideas generated, we worked to ensure that all participant voices were present across the fragments to ensure that no one voice dominated. The genre of the fragment (i.e. voice, tone, form, and function) shaped each fragment. A range of genres were used to enable the archive to voice the personal, public, professional, and commercial interests that Interactive Skin circulates within. Each table used the four analytical themes (outlined earlier) to draw together collections of direct quotes and paraphrased ideas from participant-collaborator interviews and probe returns; and the data from the speculative workshop, which was organized into specific time blocks on a 50-year future timeline, including direct quotes from participant-collaborators, and ranked by the lead of the HCI Lab in terms of priority (low, medium, high).

The writing process ensured a strong connect between the research data and their fictionalization in each fragment to imbue them with "real-life" fidelity. This process is made visible in Figure 2, which shows an excerpt of Fragment 2 (an e-mail exchange between colleagues on regulation): the italicized text represents the direct quotes from interviews and probe returns, and the underlined text represents direct comments from the speculative workshop (Phase 3).

The archive fragments were drafted by the lead author and reviewed and revised by the coauthors. They were then shared by author three with 10 lab-members in the regular weekly lab meeting to garner their reaction and comments: this included 7 study

Our interests and concerns are certainly different from those of PureSkin and other industry players, though I hope the *flow of people between academia and industry* might help – a couple of our Postdocs recently joined the PS full-body VR skin-haptics development team. Others are *designing outside of commercial interests leading the use sustainable, compostable materials;* another has joined a *radical research group working with skin cells*; and one of our postdocs is key in the 'skinless movement fighting for skin to remain unaltered' and against big tech-pharma's monopolisation of the skin. So yes, I agree with you – IS, *is* a complex arena! In-the-wild deployments of skin modification and implants are starting to make IS an accessible trend, hastened by more designers preparing to enter the market, new start-ups kicking off, and the new permits for tattoo artists to imbue electronics in their designs. Ultimately, don't we *all* want interactive skin to come in from the '*Wild-west*'?

Figure 2. Illustration of the processing of embedding the research data within each fragment.

Research note written by a researcher regarding a one-week user-study of a new interactive skin prototype: dated w/b 18.05.2044. It reports their observations, questions, and preliminary comments on the prototype design.

All Ps had a full and 'smooth' experience of IS60 for the duration of the study: the technology was robust and held up in a wide range of use contexts.

The materiality of IS60 performed well, the breathable Substrates functioned well with no sweat build-up and no adverse reactions (or after markings at the end of the study) were reported. Several Ps commented positively on the *surface texture and temperature. Many commented on its 'bounciness' "I'm pushing and it feels like it's pushing back",* a familiar sense of *'squishiness'* and *feeling of 'body fat and stretch-ability' (key to joint movement),* with all agreeing on *it being soft, curved, formable, and breathable*. The majority of participants signalled it is vital that IS60 *does not radically alter the look and feel of skin, and should adapt to existing tattoos, skin marks or scars*. A few saw the potential of IS60 to camouflage or improve the skin and raised the possibility of working with a different material palate.

Aesthetics: Most Ps either liked the visual and tactile aesthetic of IS60 or felt it so neutral as to be unimportant. A few Ps, however, described it as *"odd", "cyborgy" or "geeky" and stressed the importance of not to approach the skin like a flat, cold interface. Several Ps (see P 22, 24 and 20) voice concern over the stigmatising potential of IS60 especially regarding rehabilitation.*

Activation/deactivation was an issue, the 30 participants in the study were asked to keep the IS60 active for the entire study period (i.e., 24/7 for 7 days) to allow for testing of *breathability, social acceptance* etc (see IS60_US_2004.docz). Around 20% (check) of participants mentioned (in passing) that they had deactivated the IS60 at least once during the study (e.g., P4 deactivated IS60 in bed *each* night). I probed - all related to *a level of fear/distrust "I don't feel safe or secure to be close to cameras and microphones" and "in some situations, the closeness to my body threatens our privacy"*.

Connection: Surprised extent that IS60 generated a sense of connection between many of the participants. E.g., P10 commented "could *start a conversation with other people, we had something in common, we are both interested in same thing*" This was particularly the case when using it to guide their movement in sports contexts and rehabilitation situations.

Misrecognition: Quite a lot of incidences where a *P would not perform a simple micro-gesture due to concern over 'misrecognition' – nearly all Ps expressed high-level of concern re gestures/ movements being misunderstood as sexual*. Interestingly the new 'hover' interaction function was seen by some (though not all) Ps, as having the greatest potential for misrecognition given its new form. This *limited Ps' use of IS60*. Suggests perhaps more *discrete functionality* and *skin-matching* may be needed. Countering this, however, other Ps noted that interactions *should not 'be secretive", 'Hidden/invisible' or 'too discreet'* (e.g., Ps 2,7, 10, 20, 23, 25) and that *others 'should be aware that you are interacting with a technology*'. So a hard design balance – and one that needs more exploration.

Figure 3. Fragment 1, a page from a research journal (dated 2044) written by a researcher regarding a one-week user-study of a new interactive skin prototype.

Felt benefits: *Most participants felt strongly that IS60 interacting on the skin made a huge difference to the different psychological and perceptual affects they gained from the materials. Others suggested they newly recognised surprizing details of objects textures (including sounds), temperatures and feedback.* P7 "There are some trade-offs, the skin gives you some feedback but it is also deformable" Several Ps noted gaining a strong sense of inner body sensation via IS60.

Social acceptance: A significant number (check – around 25%?) commented that people *are not quite ready to see people interacting with the skin in a social context.* E.g., P16: *"interacting on an external device like a mobile is seen as okay – its expected, but the body and skin is too personal".* Remember to ask colleagues in sociology department about their findings from 'societal transitions toward on-body interface' project, to gauge whether this response is unique to IS60 or reflects broader contemporary themes.

Body location: *All participants commented on the prime importance for body locations and its link to governing the types of interactions IS60 afford*. With the new materials and simplified process of applying to the skin no area of the body was considered too geometrically challenging, and IS60 achieved full-body surface sensation. Much focus group discussion of the boundary between body and skin – and several Ps commented on a positive feeling that their boundary as a person was being shifted via IS60: bringing them closer to other wearers. This relates to comments on '*skin to skin symbiosis' in relation to the body warming IS60.* There was some discussion or concern re how or whether IS60 could become part of or disrupt people's body schema'.

Initial Qs/comments on the implications of the study for the prototype design
The study indicates some clear *concerns that need to be bridged/addressed by design* Consider *the scope/balance* of IS60 *interface to offer more discrete, subtle, multi sensorial forms of interaction* whilst avoiding sense of '*hiding' the device. Q: Should we take one step further with interfaces reacting e.g., using colour, lights or movement?* This relates to the Q of whether we could/should look at extending our material palate inspired by natural/bio materials to explore relations of objects with skin differently?

We might explore the link between IS60 *and body location further – and the social reasons underpinning when Ps move and reposition it?*

Re design *to enable the interactions* necessary for the functionality of IS60 *to be fully in-the-wild* we need to better understand *the societal transitions required and how to foster these to enhance social acceptance of skin as device. Links to point below re deactivation, but also more generally to customising to people's uses, needs, skin and bodies.*

People *move through different environments throughout the day*, need to consider how to design IS60 to flex to the *very different sets of social constraints it is used in: maybe a set of levels? How and when might deactivation be advised/designed in to IS60?*

The study suggests we may need to understand how IS60 is provoking a merging of physiological sensorial, perception and embodied experiences: particularly in relation to body boundaries and sense of self or connection with others.

As with previous studies, suggests need to continue to explore questions of the possibilities for realistic vs novel experiences

Figure 3. Continued.

Archive fragment: email correspondence

From: [redacted]
Date: Monday, 14 February 2066 at 15:21
To: [redacted]
Subject: SI Reg

The speed of development of the materials and manufacturing is very exciting, and the increase in commercial interest opens up more possibilities for scaling up. However, it is essential that we input into the regulation debate to manage the *commercial interests and potential consequences of the social and sensory exploitation of body and its data.*

Our interests and concerns differ from those of PureSkin and other industry players, though I hope the *flow of people between academia and industry* might help - a couple of our Postdocs recently joined the PS full-body VR skin-haptics development team. Others are *designing outside of commercial interests leading the use of sustainable, compostable materials*; *another has joined a radical research group working with skin cells*; and one of our postdocs is key in the 'skinless movement fighting for skin to remain unaltered' and against big tech-pharma's monopolisation of the skin as a material. So yes, I agree with you - IS, *is a complex arena!* In-the-wild deployments of skin modification and implants are starting to make IS an accessible trend, hastened by more designers preparing to enter the market, new start-ups kicking off, and the new permits for tattoo artists to imbue electronics in their designs. Ultimately, don't we *all* want interactive skin to come in from the '*Wild-west*'?

At yesterday's lab meeting I suggested a regulatory framework that speaks to the institutional, commercial and personal. I suggest we build on the 2062 academic ethical guidelines re 'on-body/on-skin user interfaces design and user testing' to help position the various actions being considered. Of course, there's no consensus in the team… have set out some initial starting points re possible key areas/questions of concern as I see them:

- Material standards: including material breathability; guaranteed non-skin-fusing; *bio-compatibility; use of bio-materials; protocol for development of new materials*
- Environmental standards: *sustainable cycle/recycle and disposal procedures*
- Manufacture standards: classifications of IS initiatives e.g., medical, aesthetics, communication, and permitted functions; agreement on the level of autonomy over input and output functions permitted by elements of IS (i.e. regulation of user vs device control); *on-skin/in-skin protocol*
- Security standards: anti-hacking protection, privacy measures, skin-ownership
- *User standards: protocols and regulations on the use of IS and the relationship to on/in skin may be required (?)*

Figure 4. Fragment 2, an e-mail exchange (dated 2066) between the lab lead and ex-colleague who has moved from academic research into a governance/regulation role.

Interested to hear your thoughts - [redacted] will be in touch to arrange a meeting.

Regards

Professor [redacted]

From: [redacted]
Date: Friday, 11 February 2066 at 15:21
To: [redacted]
Subject: SI Reg
We have been investigating the aesthetic feel of the new Interactive skin devices from [redacted], there is a concern about their *overly 'live-ness'*. We are doing provoked-aging tests in response to rumours that the developers have added *bio-material to improve its skin-feel*. [redacted] is so concentrated on the commercial *pursuit and exploitation* of IS aesthetics that perhaps this is just a sophisticated altering *look and feel of the skin. I do think it differs from wearable devices*, as *with IS the user is interacting with their own body and surely that makes a difference?*

Have you heard anything about the [redacted] lab's work on a new 'Camouflage' skin? Apparently, others in the lab are working on 'Reveal', *emotional displays via the skin including an em-tattoo.* These displays remind us that what *the skin covers and what you feel is actually the inside of your body*.

Perhaps these developments will blur the distinctions between IS/skin too much? That is something that needs to be at the centre of any regulation: OK *seamlessly integrate with your skin and ideally give it similar properties - soft, curved, formable, breathable, but IS should not radically alter the look and feel of skin. It can augment the body and its boundaries, amplify some aspects of the skin but it should always connect to a 'realistic' skin experience.* The ethical complexity of *IS reflects its reach across the level of the cell to ecology and individual to societal, as* Mitochondria illustrates this complexity feeds into ethical and practical design questions on 'skin borders'… *maybe people want parasites in their IS devices, maybe these can produce the energy to power them?*

It's the same arguments we had decades ago when we insisted *ethical conversations needed to take place* before mass production. [redacted] would argue its 'Not yet ethical as not in wild' and that privacy, security and all our other concerns were pertinent to any technology. Wonder what they made of the 2069 PureSkin Hack! What was it 50 million users with their bodies momentarily held as ransom-wear?

Would be helpful to discuss

Best
[redacted]
Emergent Tech consulting

Figure 4. Continued.

Figure 5. Fragment 3, an advert for Pure skin (dated 2071).

participant-collaborators and 3 new lab members with backgrounds in computer science, HCI, design, and engineering. The three archive fragments were sent by e-mail, along with the task to read them and consider two questions from their personal standpoint: (1) Do the fragments work as research provocations to agitate the socio-technological space of interactive skin futures and the design/research around it? Do these fragments trigger new ideas and thoughts about interactive skin? And if they do, what kind of ideas, discussion do they prompt? (2) What would you add/change re any of the fragments? What did/didn't work for you? One day later, the participants shared their responses in a live meeting. The participants engaged fully with each of the fragments that appealed to them in different ways.

Findings & discussion: speculative narratives on interactive skin futures

In this section, we first present three speculative fragments from the found archive on Interactive Skin futures, second, we discuss participant-collaborators responses to them, and third we reflect on the limitations and potentials of a socially orientated speculative approach.

Speculative fragments from a found interactive skin archive

The fragments are designed to prompt dialogue between social and sensory research and Interactive Skin research/design and to provoke further reflection on skin/Interactive Skin.

Fragment 1: a page from a research journal

The use of the research note genre in fragment 1 affords a professional, procedural voice reporting observations and gives voice to the imagined study researcher and participant

questions, and preliminary comments. The fragment content engages with participant-collaborator comments and concerns related to the social, sensorial, and technological use of Interactive Skin, with particular focus on the sensory experiences of (interactive) skin. The fragment also relates to skin studies conceptualization of skin-scapes, and the exploration of the experiential, social, and biological ever-changing dynamics of skin.

Fragment 2: an e-mail exchange

The e-mail exchange genre used in fragment 2 provides a mixture of a personal and professional tone, the factual and anecdotal, and engages with the spheres of social and bio-implications, as well as those of commerce and development. The fragment's use of written text and dialogue affords the characters in the exchange the space to develop their points independently and sequentially. It is composed to draw attention to participant-collaborator concerns about materiality through a focus on materials, manufacturing processes and the interaction of interactive skin with the human skin. Simultaneously, it links to the skin studies concept of the boundary of the skin, the skin as living, and skin-hacking. Its discussion of regulation at an imagined and contested tipping-point heralding the mass-commercial production of interactive skin serves to foreground social ethical issues.

Fragment 3: an advert

The advert genre selected for fragment 3 offers a public commercial lens through which to engage with the sociality of interactive skin theme and situates the technology in the socio-cultural and sensory work of the skin. The genre brings a hyperbolic voice of promise to the skin and points to its commercialization in relation to lifestyle, esthetics and health, linking to the skin study concepts of skin projects, skin modification, and augmentation.

The theme of ethics is embedded across the three fragments and serves to connect them. For example, a concern with regulation implicitly links the research journal note (F1) via the report concerns about security and safety, while the e-mail discussion (F2) comments on activity outside of regulatory frames, and a footnote in the advert (F3) comments on questions of compliance, health and security regulations and manufactory guidelines.

Agitating the socio-technological space of interactive skin

The participant-collaborators responses to the fragments varied. All found them interesting, with most finding them "fascinating," "charming and provocative," or productively "disturbing," with the potential to aid the generation of new ideas. A few participants – particularly those who had not participated in the study, found the format unfamiliar and confusing, "I thought it is cool but could not relate directly." (We return to this issue in the limitations of the approach.)

The fragments worked to agitate the socio-technological space of Interactive Skin. Individually, each fragment prompted discussion of a variety of social and sensory ideas.

The discussion of the research note (F1), prompted discussion of the discreet, secretive, and awareness aspects of Interactive Skin with attention to the challenge of the social acceptance of new technologies. This generated reflection on the extent and speed with

which people become accustomed to new forms of digital communication (e.g. talking to themselves in public with earphones). However, one participant expressed frustration at the fragment's suggestion that "we will have the same problems in 30 years as we did 20 years ago." In contrast, one found fragment 1 the most powerful in that it, " . . . worked very well to give an integrated and concise account of many technical, sensory, social and ethical challenges and future avenues." Overall, this fragment provoked less response from participant-collaborators than the other fragments, a finding we return to in the next section.

The e-mail exchange (F2), included reference to "interactive skin that lets you feel what is under the skin surface." This led to a discussion of the sensory experiences of the skin, and how Interactive Skin might "let you feel what is inside your body" and inspired one participant-collaborator to take the idea forward in their design. Another was particularly struck by the idea/phrase in the e-mail of "people being skinless." She "felt weird about it" and found its implications "scary." The notion of a "skinless movement" was particularly provocative and triggered discussion of the ethics of Interactive Skin. The social starting points embedded in the fragment also triggered new technological design ideas, for instance, "Camouflage skin" invited speculations on high-resolution large-scale and real-time visual sensing and output embedded inside Interactive Skin. The fragment also prompted speculation on the possibilities and challenges of "emotional displays" via Interactive Skin and the design of interfaces that are parasitic and powered by the skin. While these ideas were experienced as "very fresh and interesting," they actually emerged from the research encounter with the group, suggesting (as we discuss in the next section) that the fragments served as a kind of refractive mirror.

The advert (F3), prompted discussion of a range of topics. The "layer subscriptions" as a potential business model was discussed, including what the layers might include, for example, it was suggested the "The Aesthetics subscription could also include a visual display functionality, e.g. for different skin colour, ornaments or dynamic effects." The fragment encouraged a sensitivity to the wider context of Interactive Skin, provoking discussion of economic and political ideology factors in the governance and proliferation of future technology including the undesirable/desirable aspects of calls for larger skin displays, "chameleon skin," and discussion of the racial aspects (skin tone) of Interactive Skin. The "no skin fusion" promise in the advert prompted discussion of the extent to which it is desirable or appropriate for a device to seamlessly interweave or form a symbiosis with the human body and the extent to which it should be separate/not-fusing. The closeness of the advert to "what the cosmetics industry wants to do" made it less provocative to a few participant-collaborators, one of who commented they found it disturbing, "all this amazing tech development may go into this superficial app that has so many ethical issues . . . [and] imbues traditional notions of beauty" although they also found the fragment a helpful provocation, "all those little buzzwords encapsulate all those different things."

Collectively, the fragments prompted discussion of Interactive Skin futures time-line, the challenge of social concerns that may emerge, and the value of applications of Interactive Skin.

As an archive, the set of fragments prompted discussion and reconsideration of the time-line of Interactive Skin futures, with the proposal that the dates on each fragment (which reflect the initial speculative time-line of the group) be brought forward by 25–

30 years. This was on the evidence of breakthroughs in interactive computing from basic research to wide market adoption: for example, basic research on Multi-touch input by Bill Buxton and others in the 80s and the iPhone in 2007; and influential work on AI agents/recommender systems by Pattie Maes and others in the 1990s and their wide adoption in 2010s.

The fragments were understood as reflecting contemporary technological concerns (e.g. privacy, business models) which were not major issues for technology 30 plus years ago. This provoked reflection on the challenge of the social concerns that the use of future technologies might generate, and what new problems might dominate the future. This led to speculative envisioning of what various contemporary technologies could have been like if privacy had been thought of at the time of their design. In the case of Interactive Skin, the fragments generated discussion of what should be displayed and where, the scalability of Interactive Skin to large surfaces what should be sensed, and how far participant-collaborators should go with their development.

The fragments provoked questioning of the primary applications that the Interactive Skin community is focused on. The fragments triggered critical thoughts on the nature and value of some plausible future applications, on the business models behind them and more generally on what a pervasive use of interactive skin may entail for the individuals who use or perhaps even more importantly do not use it because they either prefer not to or because they do not have the opportunity (e.g. due to cost). This led to a discussion of meaningful applications beyond the aesthetic and cosmetic (e.g. for communication, wellbeing and health, and work).

Reflections on a socially orientated speculative approach

Limitations

As noted earlier, the speculative fragments were unfamiliar and confusing to a few participants. This highlights the importance of preparing the ground for the use speculative provocations, such as these to ensure they "land" well, for example, familiarizing the participants with the characteristics and purpose of a speculative narrative and clarifying expectations for their use. While such grounding was part of the study design, on reflection it would have been beneficial to revisit this prior to sharing the fragments with the three new lab members.

Overall, fragment 1 provoked least reaction from participant-collaborators. The format and the content appear to have been too familiar to participant-collaborators and as a result lacked the necessary distance and dissonance to provoke. Similarly, while participant-collaborators recognized the materiality theme across the three fragments, these were perceived as less provocative because the aspects covered were "quite well in sync with our understanding." One participant-collaborator suggested a need for "more provocative, more disturbing application cases that are farther from mainstream." Fragment 3 provoked the most discussion, suggesting that genres that may be familiar yet sit outside of the everyday work of a team, and visual formats may be most appropriate and successful. Finally, several participant-collaborators commented that the fragments were "overly biased toward the negative" and wanted to see some more positive inspirations: a reminder to social researchers to reflect on and be more alive to the pervasiveness

of negative responses to technology within our framing and development of future fragments.

Potentials

Despite the limitations outlined above, the speculative narrative created through the archive of found fragments bridged interdisciplinary concepts, prompted dialogue, and shed light on the interconnection between the senses, social issues, and technology in the context of Interactive Skin, an example of an emergent affective techno-touch.

Having multiple and diverse fragments with different formats was considered helpful in conveying that there is not only one plausible future, "to render the conflicting perspectives on this complex matter" and to help "different people to connect" with the social and sensory aspects of Interactive Skin. The strength of reaction that participant-collaborators had to the fragments was key to their value and encountering them together in a meeting gave space to different reactions and reflective discussion.

As already noted, although the fragments are composed directly from quotes and comments from the research collaboration data, participant-collaborators described the ideas and the approach as "fresh and interesting." The social/sensory lens of critical skin concepts (outlined earlier) enabled the fragments to disrupt, agitate, and attune the participant-collaborators' ideas, and to "play them back" to them. It is their refraction and re-configuration through that social/sensory lens that made them a new resource for thinking and design. One participant-collaborator described the fragments as acting "like a mirror that reflects back the points and issues that we have communicated in the initial study – but it reflects in a transformed and provocative way: by putting different emphasis, and elaborating on aspects or giving concrete examples, mediated by the perspective and the creativity of researchers with a different disciplinary background. A magic mirror that lets us see the known in a transformed way … and add new perspectives."

More generally, the fragments proved valuable in that they opened up the techno-space of Interactive Skin to reveal complex/multifaceted experiences and imaginations. They offered a novel way to collaboratively engage with different disciplinary conceptualizations of skin, facilitate discussion of socially sensory informed Interactive Skin futures, such as types of possible devices, application, and insights on how it might feel to live with Interactive Skin. The HCI participant-collaborators found many interesting dimensions in the fragments, and hope to use the fragments to aid their future thinking and to speculate on design. The social researchers' approach to the skin has been stretched by their research encounter with HCI to broaden their understanding of the opportunities for the skin as a fluid site for interaction and augmentation.

The created fragments are interesting research outputs in themselves and worked well as a "refractive mirror" for study participants. In addition, both the cultural probes used in the study, and the speculative archive fragments generated through the study could be deployed as cultural probes to support future work into interactive skin (including with new participants who did not contribute to our original study). For example, they could be used to provoke discussion, to inform rapid-prototyping, engage with possible futures, or to generate new archive fragments. The latter would be particularly helpful in conveying that the multiplicity of plausible futures, and the contradictory and conflicting elements circulating in relation to Interactive Skin.

This work offers a novel format for the exchange of speculations and ideas that could be extended through a future study (e.g. a workshop or web-based-project) bringing together social/sensory and HCI researchers to generate new speculative fragments for the archive.

Conclusion

The speculative narrative on interactive skin presented in this paper in the form of three fragments from an imagined found archive, represents a critical understanding of interactive skin. The fragments are research outputs in their own right, which successfully provoked and initiated critical interdisciplinary conversations with value for research and design. Collectively, the fragments foreground questions of the sociality, sensorial experience, materiality, and ethics of interactive skin through a speculative lens on skin studies and HCI. They offer routes to explore the messy, contradictory tensions and discourses that circulate around Interactive Skin as an emerging technological design space. This approach can help to translate social and sensory concerns into tangible design considerations to inform the development of Interactive Skin. Collaborative work between HCI design and social/sensory researchers, such as that presented in this paper, thus has the potential to advance the creative use of a speculative approach as a research method to ask questions, generate new connections and "stay with the trouble" (Galloway and Caudwell 2018, 95).

Acknowledgments

We would like to thank the participant-collaborators in the study, InTouch colleagues for discussion on writing speculative narratives, and Lili Golmohammadi (InTouch team) for advice on the development of cultural probes.

Disclosure statement

The authors report there are no competing interests to declare.

Funding

This research was funded by the European Research Council (ERC), InTouch: Digital Touch Communication project, grant number 681489 and Interactive Skin: Digital Fabrication of Personalized On-Body User Interfaces, grant number 714797 H2020 European Research Council.

Notes on contributors

Carey Jewitt is Professor of Technology and Learning at UCL Knowledge Lab in the Dept of Culture, Communication and Media (UCL IOE), and Chair of UCL Collaborative Social Science Domain. Her work explores how the use of digital technologies shapes interaction and communication, engages with interdisciplinary methodological innovation and contributes to the development of multimodal theory. Carey is Director of InTouch an ERC Consolidator Award which investigates the sociality of digital touch technologies for future communication. She has led many interdisciplinary research projects funded by the ERC, ESRC, EPSRC, British Academy and a number of charities. Carey

is a founding editor of two SAGE journals, Multimodality & Society, and Visual Communication. Her recent publications include the book, Interdisciplinary Insights for Digital Touch Communication (2020) and alongside articles including in New Media & Society, Information, Communication & Society, ToCHI, and Qualitative Research.

Ned Barker is a Senior Research Fellow at UCL Knowledge Lab, in the Dept of Culture, Communication and Media, IOE, University College London. He is a sensory ethnographer and his research interests are based upon exploring the complex relationships between the body, technology, and society. Ned has led research that investigates the ways in which industrial robots shape the social and sensory conditions of manual labour on the InTouch project, and has been awarded a Leverhulme Trust Fellowship titled 'Biohybrid bodies: a sociological for living with Living Machines' (October 2021-2024). Ned recently published a chapter titled 'An Ethnographer Lured into Darkness' exploring methodological reflections on sensory research (Barker, 2020), and has published in the areas of: Sports Coaching; Performance Art; Industrial Robotics; and Education.

Jürgen Steimle is professor at the Department of Computer Science at Saarland University and Saarland Informatics Campus. He directs the Human-Computer Interaction and Interactive Technologies Lab. He has held positions as Independent Research Group Leader at Saarland University (2013-2016) and Senior Researcher at the Max Planck Institute for Informatics (2013-2018). From 2012 to 2014, he was a Visiting Assistant Professor at Massachusetts Institute of Technology (MIT). He holds a PhD in Computer Science from Darmstadt University of Technology. His research investigates embedded and embodied user interfaces that seamlessly merge with the physical world and the human body, to enable more effective, expressive, and engaging interactions with computers and interactive devices. His work was recognized with an ERC Starting Grant, best paper awards at premier conferences in human-computer interaction (e.g., ACM CHI and UIST). He is serving as co-chair and member of program committees for major international conferences, including positions as general co-chair at ACM ISS 2017, program co-chair for ACM TEI 2017 and workshops track co-chair for CHI 2014 and CHI 2015.

References

Aditya, Nittala, Klaus Kruttwig, Jaeyeon Lee, Roland Bennewitz, Eduard Arzt, and Jürgen Steimle 2019. "Like a Second Skin." in Proceedings of CHI Conference on Human Factors in Computing Systems (CHI '19), 4–9 May 2019, Glasgow, Scotland UK. ACM, New York, NY, USA. doi:10.1145/3290605.33006.

Ahmed, Sara, and Jackie Stacey. 2001. *Thinking through the Skin*. London: Routledge.

Alexander, Jason, Anna Roudaut, Jürgen Steimle, Kasper Hornbæk, Miquel Bruns Alonso, Sean Follmer, and Timothy Merritt 2018. "Grand Challenges in shape-changing Interface Research." In Proceedings of the CHI 2018, Montreal, QC, Canada, 21–26 April 2018; ACM: New York, NY, USA, DOI: 10.1145/3173574.3173873.

Atkinson, Paul. 2015. *For Ethnography*. London: Sage.

Auger, James. 2013. "Speculative Design: Crafting the Speculation." *Digital Creativity* 24 (1): 11–35. doi:10.1080/14626268.2013.767276.

Barker, Ned, and Carey Jewitt. 2023. "Sensory Explorations of Digital Touch: Tactile Apprenticeship and Interviews, Chapter 13." In *Routledge Handbook of Sensory Ethnography*, edited by Philip Vannini. London: Routledge.

Bell, Francis, Gordon Fletcher, Anita Greenhill, Marie Griffiths, and Rachel McLean. 2013. "Science Fiction Prototypes: Visionary Technology Narratives between Futures." *Futures* 50: 5–14. doi:10.1016/j.futures.2013.04.004.

Benthien, Claudia. 2002. *Skin: On the Cultural Border between Self and World*. New York: Columbia University Press.

Blythe, Mark 2014. "Research through Design Fiction: Narrative in Real and Imaginary Abstracts." In Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14, ACM Press, Toronto, Ontario, Canada, 703–712. doi:10.1145/2556288.2557098.

Borgerson, Janet, and Jonathan Schroeder. 2018. "Making Skin Visible: How Consumer Culture Imagery Commodifies Identity." *Body and Society* 24 (1–2): 103–136. doi:10.1177/1357034X18760987.

Braun, Virginia, and Victoria Clarke. 2019. "Reflecting on Reflexive Thematic Analysis, Qualitative Research in Sport." *Exercise and Health* 11 (4): 589–597. doi:10.1080/2159676X.2019.1628806.

Ciaunica, Anna, Andreas Roepstorff, AKaterina Fotopoulou, and Bruna Petreca. 2021. "Whatever Next and Close to My self—The Transparent Senses and the "Second Skin": Implications for the Case of Depersonalization." *Frontiers in Psychology* 1219.

Davison-Vecchione, D, and S. Seeger. 2021. "Ursula Le Guin's Speculative Anthropology: Thick Description, Historicity and Science Fiction. *Theory*." *Culture & Society* 026327642110517. doi:10.1177/02632764211051780.

Dunne, Anthony, and Fiona Raby. 2013. *Speculative Everything: Design, Fiction, and Social Dreaming*. Cambridge, MA. USA: MIT Press.

Flanagan, Mary, and Austin Booth. 2007. "A Skin of One's Own: Toward A Theory of Transsexual Embodiment." In *Re: Skin.* , edited by Mary Flanagan and Austin Booth. Cambridge, MA: MIT Press: 1–16.

Galloway, Anne, and Catherine Caudwell. 2018. "Speculative Design as Research Method: From Answers to Questions and "Staying with the Trouble." In *Undesign: Critical Practices at the Intersection of Art and Design*, edited by Gretchen Coombs, Andrew McNamara, and Gavin Sade. Oxon, UK: Routledge: 85–96. doi:10.4324/9781315526379-8.

Gerlach, Neil, and Sheryl Hamilton. 2003. "Introduction: A History of Social Science Fiction." *Science Fiction Studies* 30 (2): 161–173. http://www.jstor.org/stable/4241163

Golmohammadi, Lili. 2022. "How to Use Online Probes for Social Science Research." In *SAGE Research Methods: Doing Research Online*. SAGE Publications. doi:10.4135/9781529605990.

Gorjanc, Tina 2019. "Investigating the Consumer Vs. Citizen Paradox Present in Each Individual." https://speculativeedu.eu/interview-tina-gorjanc/

Hanna, Julian 2020. "Speculative Edu Project." https://speculativeedu.eu/about/

Harris, Anna, and Marilys Guillemin. 2012. "Developing Sensory Awareness in Qualitative Interviewing: A Portal into the Otherwise Unexplored." *Qualitative Health Research* 22 (5): 689–699. doi:10.1177/1049732311431899.

Howes, David. 2018. "The Skinscape: Reflections on the Dermalogical Turn." *Body and Society* 24 (1–2): 225–239. doi:10.1177/1357034X18766285.

Howes, David, and Constance Classen. 2014. *Ways of Sensing*. London, UK: Routledge.

Jewitt, Carey, Ned Barker, and Lili Golmohammadi. 2022. "Creative Probes, Proxy Feelers, and Speculations on Interactive Skin." *Multimodal Technology and Interaction* 6 (22). doi:10.3390/mti6040022.

Jewitt, Carey, Jeff Bezemer, and Kay O'Halloran. 2016. *Introducing Multimodality*. London: Routledge.

Jewitt, Carey, Dimitri Chubinidze, Sara Price, Nikoleta Yiannoutsou, and Ned Barker. 2021. "Making Sense of Digitally Remediated Touch in Virtual Reality Experiences." *Discourse, Context and Media* 41: 100483. doi:10.1016/j.dcm.2021.100483.

Kao, Cindy Hsin-Liu, Manisha Mohan, Chris Schmandt, Joseph Paradiso, and Katia Vega 2016. "ChromoSkin: Towards Interactive Cosmetics Using Thermochromic Pigments." In proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems. Association for Computing Machinery, New York, NY, USA: 3703–3706. Doi: 10.1145/2851581.2890270.

Lafrance, Marc. 2018. "Skin Studies: Past, Present and Future." *Body and Society* 24 (1–2): 3–32. doi:10.1177/1357034X18763065.

Mason, Jennifer, and Katherine Davies. 2009. "Coming to Our Senses?" *Qualitative Research* 9 (5): 587–603. doi:10.1177/1468794109343628.

Mitrović, Ivica 2019. "Introduction to Speculative Design Practice". http://speculative.hr/en/introduction-to-speculative-design-practice/

Mueller, Floyd 2020. "Next Steps for Human-Computer Integration." In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20). Association for Computing Machinery, New York, NY, USA, 1–15.

Parisi, Luciana. 2012. "Speculation: A Method for the Unattainable." In *Inventive Methods: The Happening of the Social*, edited by Celia Lury and Nina Wakefield, 232–244. London: Routledge.

Price, Sara, Carey Jewitt, Dimitri Chubinidze, Ned Barker, and Nikoleta Yiannoutsou. 2021. "Taking an Extended Embodied Perspective of Touch: Connection-Disconnection in iVR." *Frontiers in Virtual Reality* 2 (April): 1–20. doi:10.3389/frvir.2021.642782.

Ross, Jen. 2017. "Speculative Method in Digital Education Research." *Learning, Media and Technology* 42 (2): 214–229. doi:10.1080/17439884.2016.1160927.

Salazar, Juan, Sarah Pink, Andrew Irving, and Johannes Sjöberg. 2017. *Anthropologies and FuturesResearching Emerging and Uncertain Worlds*. London: Routledge.

Savransky, Martin, Alex Wilkie, and Marsha Rosengarten. 2019. "Introduction:The Lure of Possible Futures: On Speculative Research." In *Speculative Research: The Lure of Possible Futures*, edited by Alex Wilkie, Martin Savransky, and Marsha Rosengarten. London: Routledge: 1–17.

Selwyn, Neil, Luci Pangrazio, Selena Nemorin, and Carlo Perrotta. 2020. "What Might the School of 2030 Be Like? An Exercise in Social Science Fiction." *Learning, Media and Technology* 45 (1): 90–106. doi:10.1080/17439884.2020.1694944.

Steimle, Jürgen. 2016. "Skin–The Next User Interface." *Computer* 49 (4): 83–87. doi:10.1109/MC.2016.93.

Thorpe, Holly, Julie Brice, Anoosh Soltani, Mihi Nemani, and Grace O'Leary. 2022. "Methods for more-than-human Wellbeing : A Collaborative Journey with Object Interviews." *Qualitative Research* 146879412211293. doi:10.1177/14687941221129374.

Vannini, Philip. 2015. *Non-Representational Methodologies*. Oxford: Routledge.

Weigel, Martin, Aditya Nittala, Alex Olwal, and Jürgen Steimle 2017. "SkinMarks: Enabling Interactions on Body Landmarks Using Conformal Skin Electronics." In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17). Association for Computing Machinery, New York, NY, USA, 3095–3105. doi:10.1145/3025453.3025704.

Weigel, Martin, Lu Tong, Gilles Bailly, Antti Oulasvirta, Carmel Majidi, and Jürgen Steimle 2015. "iSkin," in Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15, 2991–3000. ACM, New York, NY, USA. https://dl.acm.org/doi/10.1145/2702123.2702391

Withana, Anusha, Daniel Groeger, and Jürgen Steimle 2018. "Tacttoo: A Thin and Feel-Through Tattoo for On-Skin Tactile Output." In Proceedings of the 31st Annual ACM Symposium on User Interface Software and Technology (UIST '18). Association for Computing Machinery, New York, NY, USA, 365–378. doi:10.1145/3242587.3242645.