Understanding Social Perceptions Towards Interacting with On-Skin Interfaces in Public

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ABSTRACT

Wearable devices have evolved towards intrinsic human augmentation, unlocking the human skin as an interface for seamless interaction. However, the non-traditional form factor of these on-skin interfaces, as well as the gestural interactions performed on them may raise concerns for public wear. These perceptions will influence whether a new form of technology will eventually be accepted, or rejected by society. Therefore, it is essential for researchers to consider the societal implications of device design. In this paper, we investigate the third person perceptions of a user's interactions with an on-skin touch sensor. Specifically, we examine social perceptions towards the placement of the on-skin interface in different body locations, as well as gestural interactions performed on the device. The study was conducted in the United States and Taiwan to examine cross-cultural attitudes towards device usage. The results of this structured examination offer insight into the design of on-skin interfaces for public use.

CCS CONCEPTS

• **Social and professional topics** → **Cultural characteristics**; • **Human-centered computing** → *Empirical studies in HCI*.

KEYWORDS

On-Skin Interfaces, Gesture Interactions, Social Perceptions

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1 INTRODUCTION

Sensor device miniaturization has enabled technology to move directly onto the skin surface. These on-skin interfaces offer enhanced applications ranging from healthcare [1], beauty technology [25], and virtual and augmented reality [2] to everyday user interaction. The wearable computing community has developed on-skin interfaces using inexpensive materials and user-friendly fabrication processes to bring on-skin interfaces out of advanced laboratories and into daily life. However, the challenges of such on-skin systems lie not only in the technical implementation. As these on-skin interfaces will become an indelible part of the wearer's appearance, designing for *social acceptance,* is vital for their eventual public wear. In the use case of designing an on-skin touch sensor (i.e., input device), factors for consideration include the placement of the interface, as well as the wearer's gestural interaction with the device. It is crucial to design for social acceptability to integrate such systems into daily life.

Due to the nascent nature of on-skin interfaces, little research has been conducted to understand their social acceptability. However, from commercialization and research efforts in other wearable form factors such as accessories and e-textiles, the importance of understanding social convention for designing wearable systems is evident [7, 14, 20, 21].

Fully-functional and high-performing devices have been abandoned since their appearance was not considered [7].

While previous studies have explored first-person perceptions towards various gesture control techniques [16, 22], limited research has explored third-person (i.e., social) perceptions towards a user's interactions with a wearable system [20, 21]. Profita et al. [20] conducted a survey study to understand social perceptions towards an e-textile system and Rico et al. [21] investigated perceptions towards mobile device gestures, but none have ventured into the realms of on-skin interfaces. To this end, we developed an on-skin touch sensor called ***SkinSwipe***, which we used to conduct two evaluations: the first exploring perceptions towards on-skin interface placement, and the second on gestural interactions on the skin. These research questions were conducted to understand the acceptable locations for long-term wear of the system, due to the direct manipulation the occurs on the body surface. Specifically, touch interaction can trigger socially sensitive perceptions, with variable differences across cultures. For example, as discussed by Edward Hall [10] in his seminal research on proxemics, people from different cultures have varying viewpoints towards one's acceptable personal space. In the United States (US), it is not uncommon to see couples touching or holding hands in public. However, in some East Asian countries, this is less socially acceptable. To investigate cultural differences towards interacting with an on-skin interface, we conducted the study in both the US and Taiwan.

Our research aims to contribute one of the first studies examining social perceptions towards on-skin interfaces. We aim to answer the following research questions:

- What are the third-party perceptions towards the *placement* of an on-skin touch sensor?
- What are the third-party perceptions towards the *gesture interaction* performed on an on-skin touch sensor?
- What are the cultural differences towards the perceptions above for users in the US versus Taiwan?

2 BACKGROUND AND RELATED WORK

Social Acceptability of Wearable Technology

Social acceptability refers to how one presents oneself in order to be accepted by the society she is forced to disseminate into [9]. Clothing, as well as anything worn on the body, is often subject to others' viewpoints due to its visibility. What is deemed "acceptable" also varies across cultures and scenarios, as each social group may hold different value systems. Wearable computing systems offer body-borne functionalities which often come in new form factors. These novel forms can become subject to others' viewpoints in daily wear. Historically, social acceptability has been an important factor in the adoption or rejection of wearable devices. A notable example is the Sony Walkman, which was the first portable music player when introduced in 1979. The novel form factor was embraced due to a savvy marking strategy with young models cultivating the consumer attitude that it was a fashionable item to wear [6].

While there is limited research on social perceptions towards wearable technology *per se*, many research investigations have acknowledged the importance of social acceptance for device adoption [13, 24]. Guidelines on designing for wearability have identified social perceptions as a critical factor for device adoption [8, 31]. In e-textiles, Profita et al. [20] investigated social perceptions towards a textile touch sensor. Pinstripe [13], also an e-textiles project, found that people rejected certain areas for device placement based on social reasons. Toney et al. defined "social weight" [24] as the degree to which interacting with a device would hurt social interaction. Dunne et al. [7] emphasized the aesthetics of a device to be an important aspect of social communication. Specific to mobile device interactions, Ronkainen et al. [22] investigated a user's willingness to utilize a *tap gesture* for interaction. Our work seeks to extend research in social acceptability to emerging on-skin interfaces.

Impact of Cultural Norms on Wearable Tech Usage

Cultural norms play an important role in shaping one's visual perception. Cultural context [5] can often drive the physical appearance of an object. Moreover, since normative behavior is not identical across all cultures, perceptions towards technology may also vary. Campbell [4] investigated the social acceptance of talking on a mobile phone in a public setting in the US, Taiwan, Japan, and Sweden. While it was universally found to be less appropriate to talk in settings requiring collective attention, Taiwanese and Japanese participants were more tolerant of mobile phones when used in the classroom. Profita et al. [20] investigated cross-cultural perceptions towards an e-textile input device. Participants from the US and South Korea found a shared affinity for body locations of the wrist and forearm. However, there was less gender difference in South Korean participant's attitudes towards the location of the gestures. These studies highlight how cultural differences contribute to wearable technology use. We build on these studies to extend cultural investigations to on-skin interfaces.

On-Skin Interfaces

On-skin devices render the user's body as an always-available surface for input, output, and communication. Material science research from Roger's group on epidermal electronics have demonstrated fully integrated electronics that match the properties of skin [15]. However, these advanced capabilities entail high cost and manufacturing challenges, limiting them to advanced laboratories. To open access to broader populations, the human-computer interaction and wearable communities have explored low-cost, user-friendly fabrication

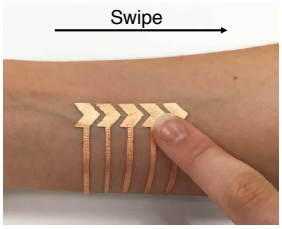


Figure 1: The swipe gesture performed on the SkinSwipe (This image was modified from [12]).

processes to create on-skin interfaces for everyday applications. iSkin [27] is a silicone based skin overlay for touch input. Skintillates [18] screen prints conductive silver ink on temporary tattoo paper to create on-skin devices. Tacttoo [30] delivers electro-tactile output thorough a thin and feel-through tattoo paper on the user's skin. DuoSkin [12] uses gold leaf to create input, output and communication devices for the skin. SkinMarks [29] screen prints on-skin I/O devices conformal to skin landmarks. However, current research has revolved around the technical development of these devices, with little to no investigation on third person social perceptions, which this research seeks to contribute.

3 SURVEY STUDY METHODOLOGY

This study investigates social perceptions towards interacting with an on-skin interface. Participants are asked to view a series of videos of the user interacting with the *SkinSwipe* system at seven on-body locations (Figure 2(a)). The online study was deployed in the US and Taiwan to uncover country-specific attitudes towards on-skin gestural interactions. While there are significant advantages in conducting an in-lab study, we choose to conduct an online survey as this format has the effect of reaching broader populations [19] for specific lines of research. The survey format also allowed us to depict the device interactions in a public, yet controlled setting. We choose to film the participants in a conference room, where two users casually bump into each other at the end of a meeting and start a brief conversation. The *SkinSwipe* system is presented as an input device that is wirelessly connected to one's mobile phone. Through a swipe gesture, *SkinSwipe* can be used to silence an incoming phone call. Participants viewed video clips of a male and a female actor who are native born to each country, and speak the primary language. This study was approved by the Institutional Review Board of Cornell University (IRB No.: *1903008656*).

Hardware

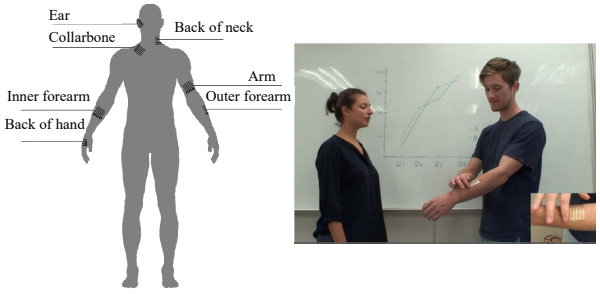
The implementation of the *SkinSwipe* device draws from the on-skin interface fabrication process developed by Kao et al. [12]. The fabrication process takes advantage of the key material of gold metal leaf, which is patterned onto thin silicone, and then encapsulated and applied directly onto the skin. The fabrication process enabled us to pattern traces which can support multiple types of one-handed gesture interactions (e.g., tap, swipe). We choose the swipe gesture as it is the most commonly supported gesture in current on-skin interface research [11, 12, 27, 29]. In our pilot study, participants also expressed a preference for swipe gestures in an on-skin context. The interdigitated touch electrodes (Figure 1) are connected to a capacitive touch controller, which filters all raw data.

Body Placement of SkinSwipe

We considered a wide range of on-body locations for the placement of *SkinSwipe*. We based this on a review of appropriate body locations based on literature in on-body and on-skin input [13, 26, 28]. We also considered wearability factors literature in identifying suitable body placement of technology [8, 17, 31]. We also looked into anthropology literature on tattoo body art [23] to understand common body locations for placing tattoos. Based on this literature survey and group discussions, we landed on seven on-skin locations (outer forearm (OF), inner forearm (IF), back of hand which will be described as hand (HD) for readability in the rest of this paper, arm (AM), collarbone, (CB), ear (ER), and back of neck (BN)) as indicated by Figure 2(a). Locations were chosen based on existing locations for conducting on-skin touch input in existing research [28], donning existing wearable devices (e.g., smartwatch worn on the wrist, earpods worn in the ear), and also tattoo body art (e.g., the arm is popular tattoo location). We selected locations that are not prone to be covered entirely by clothing or can be exposed by adjusting clothing (e.g., moving up the sleeve to expose the arm). Locations in the lower body were not considered since they were not reachable by arm's distance, and are prone to be covered by clothing.

Survey Videos

Our survey videos depicted male and female actors interacting with *SkinSwipe* at seven different on-skin locations (outer forearm (OF), inner forearm (IF), hand (HD), arm (AM), collarbone, (CB), ear (ER), and back of neck (BN)). A button press on an iPhone was also filmed and rated by participants to serve as the baseline score of what is currently considered socially acceptable. All locations (7+baseline) were filmed on both male and female actors. There were two sets of actors, one from the US and one from Taiwan. Participants were shown videos with actors from their country. In total, this resulted in 32 video interactions. The videos were shot both from a distance (2 meters) to capture the entire scene, and also as a closeup (30 centimeters) focusing on the swipe



(a) Placement (b) Screenshot

Figure 2: (a) Seven on-skin locations and (b) one sample screenshot captured from the video illustrating a US male actor swiping the on-skin device attached on his outer forearm to turn off the ringtone.

gesture. The clips were edited as such when the swipe gesture occurred on the distanced clip; it would simultaneously show the closeup clip in the bottom corner window (Figure 2(b)). After playing the edited distanced clip (15-20 seconds), the closeup clip would loop individually for one time (3-5 seconds).

We set the video scenario in a conference room where the two actors bump into each other after the meeting. They engage in small-talk, and the conversation is interrupted by one party receiving a phone call. The actor silenced the call by swiping on the *SkinSwipe* device. The actors wore a dark-colored shirt with jeans. We choose a dark color for the actor's garment since it had neutral connotations in both countries.

Study Protocol

The study consists of five parts, (1) a study introduction, (2) a qualifying survey question, (3) the on-skin interface perception study, (4) a summary questionnaire, and (5) a demographic questionnaire. The survey took 40-50 minutes to complete. After the brief study introduction, participants first completed a qualifying survey question to gauge their understanding of an on-skin device. This consisted of a short clip of a *SkinSwipe* device being operated on the inner forearm. Participants were asked to select statements that represented their understanding of the device. Only those who selected the correct statements proceeded to the on-skin perception study.

The On-Skin Interface Perception Study. The survey featured videos of actors interacting with the *SkinSwipe* system (as described in the previous section), followed by questions asking participants to rate their perceptions. The video sequence was randomly and evenly presented with regards to body location and gender. Participants first watched a video, and were then prompted to answer a series of 7-point Likert scale questions ranging from "Strongly Agree" to "Strongly Disagree." Due to the limited literature in evaluating wearable social perceptions, our questions are adapted from Profita et al. [20] and Rico et al. [21]. The questions probed participant perceptions towards the placement of the on-skin device (*Does the placement look: Normal, Private, Silly, Conspicuous, Intimate, Public, Easy to be accidentally triggered, Natural, Bothers me, Attractive, Awkward, Weird, Cool, Easy-to-access*) and the gestural interaction with the device (*Does the interaction look: Normal, Weird, Impolite, Natural, Cool, Easy-to-use, Silly, Bothers me, Awkward, Tiring, Abrupt, Easy-to-be-accidentally-triggered*). We aimed for questions that were positive, negative as well as neutral in tone to gather a wide range of perceptive.

Follow-up Questionnaire. Upon completion of the video survey, participants were asked to complete a follow-up questionnaire probing global perceptions towards the on-skin interfaces. Questions are designed drawing from Profita et al. [20]. Participants were asked to identify the ideal location for wearing the on-skin interface (not limited to the locations shown in the video). They were also asked to identify out of the seven locations shown in the survey, which two were most preferred, and which two were least preferred. We also asked open-ended questions on their concerns towards the system, what existing on-body objects the on-skin interfaces reminded them of, and what they found to be the two most important features of the device. Participants were also asked to rate if the on-skin device hindered their activities (when worn on each separate location), and if they found the on-skin interface to be useful, and their willingness to use it.

The statistical methods for analyzing the data are as follows. Independent samples t-test (Chi-squared test) were used as the statistical tests to compare the means of age (gender) distribution between US and Taiwanese group. Paired t-tests were used to check for differences in the attitudes towards the placement (or the interaction) of on-skin device collected after watching videos using an on-skin device and corresponding baseline videos using a mobile phone. To analyze the response for open-ended questions, each response underwent iterative coding independently by three experienced researchers. We use codes with a reasonable degree of agreement among different coders to identify salient concerns regarding the on-skin interface and other body locations covered in our survey based on thematic analysis [3].

4 SURVEY STUDY RESULTS AND OBSERVATIONS

In total, we recruited 200 participants for the study (100 US(41F), 100 Taiwan(51F)), aged 18-70. The average age was 28.73 (SD=7.70) for the US and 30.26 (SD=10.60) for Taiwan. The was no significant difference between age distribution (p=0.24 using independent samples t-test) and gender distribution (p=0.16 using Chi-squared test) between these

Questions	(a) United States (US)														(b) Taiwan (TW)													
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1.Normal	IF 0.04	IF 0.05	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.00	AM 0.00	CB 0.00	CB 0.00	ER 0.00	ER 0.00	BN 0.00	BN 0.00	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.00	AM 0.00	CB 0.00	CB 0.00	ER 0.00	ER 0.00	BN 0.00	BN 0.00
2. Natural	IF 0.44	IF 0.26	OF 0.18	OF 0.12	HD 0.03	HD 0.04	AM 0.03	AM 0.01	CB 0.00	CB 0.00	ER 0.01	ER 0.01	BN 0.00	BN 0.00	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.00	AM 0.00	CB 0.00	CB 0.00	ER 0.00	ER 0.00	BN 0.00	BN 0.00
3. Silly	IF 0.29	IF 0.77	OF 0.01	OF 0.22	HD 0.00	HD 0.02	AM 0.00	AM 0.02	CB 0.00	CB 0.00	ER 0.00	ER 0.01	BN 0.00	BN 0.00	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.00	AM 0.00	CB 0.00	CB 0.00	ER 0.00	ER 0.00	BN 0.00	BN 0.00
4. Weird	IF 0.29	IF 0.18	OF 0.07	OF 0.28	HD 0.00	HD 0.01	AM 0.01	AM 0.06	CB 0.00	CB 0.00	ER 0.00	ER 0.03	BN 0.00	BN 0.00	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.00	AM 0.00	CB 0.00	CB 0.00	ER 0.00	ER 0.00	BN 0.00	BN 0.00
5. Cool	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.06	HD 0.01	AM 0.00	AM 0.00	CB 0.79	CB 0.03	ER 0.02	ER 0.00	BN 0.15	BN 0.12	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.00	AM 0.00	CB 0.00	CB 0.00	ER 0.00	ER 0.00	BN 0.00	BN 0.00
6. Attractive	IF 0.00	IF 0.00	OF 0.24	OF 0.00	HD 0.41	HD 0.07	AM 0.38	AM 0.14	CB 0.82	CB 0.30	ER 0.54	ER 0.14	BN 0.13	BN 0.75	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.00	AM 0.00	CB 0.00	CB 0.00	ER 0.00	ER 0.00	BN 0.00	BN 0.00
7. Conspicuous	IF 0.55	IF 0.96	OF 0.24	OF 1.00	HD 0.87	HD 0.37	AM 0.77	AM 0.91	CB 0.19	CB 0.22	ER 0.86	ER 0.54	BN 0.66	BN 0.85	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.00	AM 0.00	CB 0.00	CB 0.00	ER 0.00	ER 0.00	BN 0.00	BN 0.00
8. Easy-to-access	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.01	AM 0.13	AM 0.02	CB 0.91	CB 0.67	ER 0.01	ER 0.04	BN 0.76	BN 0.31	IF 0.02	IF 0.02	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.32	AM 0.46	CB 0.21	CB 0.16	ER 0.72	ER 0.39	BN 0.00	BN 0.00
9. Public	IF 0.51	IF 0.33	OF 0.06	OF 0.45	HD 0.30	HD 0.92	AM 0.50	AM 0.36	CB 0.53	CB 0.35	ER 0.33	ER 0.44	BN 0.046	BN 0.00	IF 0.35	IF 0.50	OF 0.00	OF 0.02	HD 0.00	HD 0.00	AM 0.15	AM 0.33	CB 0.00	CB 0.00	ER 0.95	ER 0.63	BN 0.00	BN 0.00
10. Private	IF 0.20	IF 0.79	OF 0.47	OF 0.69	HD 0.08	HD 0.36	AM 0.26	AM 0.02	CB 0.37	CB 0.92	ER 0.92	ER 0.69	BN 0.57	BN 0.06	IF 0.01	IF 0.04	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.88	AM 1.00	CB 0.02	CB 0.02	ER 0.00	ER 0.14	BN 0.13	BN 0.12
11. Intimate	IF 0.02	IF 0.00	OF 0.89	OF 0.02	HD 0.16	HD 0.15	AM 0.01	AM 0.00	CB 0.01	CB 0.00	ER 0.24	ER 0.03	BN 0.11	BN 0.01	IF 0.00	IF 0.00	OF 0.06	OF 0.01	HD 0.00	HD 0.00	AM 0.01	AM 0.00	CB 0.00	CB 0.00	ER 0.00	ER 0.00	BN 0.00	BN 0.00
12. Triggered	IF 0.02	IF 0.049	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.01	AM 0.00	CB 0.26	CB 0.11	ER 0.11	ER 0.17	BN 0.39	BN 0.09	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.03	AM 0.01	CB 0.57	CB 0.34	ER 0.03	ER 0.30	BN 0.08	BN 0.34
13. Bothers me	IF 0.33	IF 0.00	OF 0.23	OF 0.03	HD 0.21	HD 0.44	AM 0.83	AM 0.50	CB 0.06	CB 0.04	ER 0.27	ER 0.73	BN 0.00	BN 0.16	IF 0.07	IF 0.37	OF 0.00	OF 0.09	HD 0.08	HD 0.13	AM 0.60	AM 0.66	CB 0.01	CB 0.02	ER 0.07	ER 0.76	BN 0.00	BN 0.00
14. Awkward	IF 0.17	IF 0.69	OF 0.87	OF 0.53	HD 0.01	HD 0.17	AM 0.51	AM 0.77	CB 0.01	CB 0.01	ER 0.04	ER 0.08	BN 0.00	BN 0.00	IF 0.75	IF 0.75	OF 0.27	OF 0.39	HD 0.68	HD 0.40	AM 0.09	AM 0.10	CB 0.00	CB 0.00	ER 0.03	ER 0.19	BN 0.00	BN 0.00

Table 1: (a) US and (b) Taiwan participant attitudes towards the placement of *SkinSwipe*. The presented data is compared against the baseline (i.e., mobile phone) values. Each cell indicates the level of agreement with a placement question (e.g., does this placement look *normal*?) when the device is worn on a specific location (e.g., inner forearm (IF)) and it's the corresponding *p* value (the number shown below each body location). The background of the corresponding cell is colored red (or grey) if the level of agreement towards the question is significantly higher (or lower) than that collected in the baseline case.

two groups. All Participants received a small gratuity for their time upon survey completion.

Device Placement Attitudes (Table 1)

Table 1 shows the comparison of attitudes for *SkinSwipe* body placement. The presented data is compared against baseline (i.e, mobile phone) values. We report only statistically significant results (p<0.05) for the purpose of readability.

Taiwan Participants (Table 1(b)). We report on Taiwanese participant response towards device placement in Table 1(b), reading down the rows. For Taiwanese participants, placement of the *SkinSwipe* on all body locations looked significantly less normal, less natural, more silly, more weird, more cool, more attractive, and more conspicuous. Placement is significantly more easy-to-access for the inner forearm (IF), outer forearm (OF), and the hand (HD), but significantly less easy-to-access for the back of neck (BN). The placement is significantly more public when worn on the outer forearm (OF) and hand (HD), and significantly less public when worn on the collarbone (CB) and back of neck (BN). This corresponds to the placement being significantly less private for the outer forearm (OF) and hand (HD), but significantly more private for the collarbone (CB). The inner forearm (IF) was also viewed as significantly more private. All body locations, except the outer forearm (OF) for male participants, were significantly more intimate. All upper limb regions (i.e., inner forearm (IF), outer forearm (OF), hand (HD), and arm (AM)) were significantly more prone to accidental triggering. Placement on the collarbone (CB) and back of neck (BN) were found to be significantly more bothering and awkward.

US Participants (Table 1(a)) . We report on US participant response towards device placement in Table 1(a), reading down the rows. For US participants, placement of the *SkinSwipe* looked significantly less normal, less natural, more silly, and more weird on the hand (HD), collarbone (CB), ear (ER) and back of neck (BN). Except the placement of the on-skin devices on a US male actor's outer forearm (OF), wearing on-skin devices on a US actor's inner or outer forearm looked significantly more cool and more attractive. The arm (AM) and ear (ER) also looked significantly more cool. Placement is significantly more easy-to-access for the inner forearm (IF), outer forearm (OF), hand (HD), and ear (ER).

Questions	(a) United States (US)														(b) Taiwan (TW)													
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1. Normal	IF 0.00	IF 0.04	OF 0.00	OF 0.03	HD 0.00	HD 0.00	AM 0.00	AM 0.00	CB 0.00	CB 0.00	ER 0.00	ER 0.00	BN 0.00	BN 0.00	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.00	AM 0.00	CB 0.00	CB 0.00	ER 0.00	ER 0.00	BN 0.00	BN 0.00
2. Natural	IF 0.62	IF 0.63	OF 0.29	OF 0.76	HD 0.05	HD 0.06	AM 0.16	AM 0.03	CB 0.03	CB 0.02	ER 0.13	ER 0.09	BN 0.00	BN 0.00	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.00	AM 0.00	CB 0.00	CB 0.00	ER 0.00	ER 0.00	BN 0.00	BN 0.00
3. Silly	IF 0.49	IF 0.95	OF 0.48	OF 0.25	HD 0.03	HD 0.01	AM 0.01	AM 0.01	CB 0.00	CB 0.00	ER 0.03	ER 0.02	BN 0.00	BN 0.00	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.00	AM 0.00	CB 0.00	CB 0.00	ER 0.00	ER 0.00	BN 0.00	BN 0.00
4. Weird	IF 0.06	IF 0.86	OF 0.31	OF 0.80	HD 0.02	HD 0.01	AM 0.17	AM 0.00	CB 0.02	CB 0.00	ER 0.06	ER 0.00	BN 0.00	BN 0.01	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.00	AM 0.00	CB 0.00	CB 0.00	ER 0.00	ER 0.00	BN 0.00	BN 0.00
5. Cool	IF 0.00	IF 0.03	OF 0.0495	OF 0.19	HD 0.12	HD 0.58	AM 0.31	AM 0.52	CB 0.95	CB 0.37	ER 0.01	ER 0.19	BN 0.70	BN 0.61	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.00	AM 0.00	CB 0.00	CB 0.00	ER 0.00	ER 0.00	BN 0.00	BN 0.00
6. Easy-to-use	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.01	AM 0.20	CB 0.05	CB 0.07	ER 0.01	ER 0.00	BN 0.64	BN 0.69	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.85	AM 0.43	CB 0.61	CB 0.25	ER 0.00	ER 0.00	BN 0.00	BN 0.00
7. Triggered	IF 0.03	IF 0.04	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.02	AM 0.00	CB 0.20	CB 0.07	ER 0.40	ER 0.37	BN 0.57	BN 0.25	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.03	AM 0.00	CB 0.39	CB 0.63	ER 0.05	ER 0.41	BN 0.27	BN 0.38
8. Impolite	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.00	AM 0.01	CB 0.05	CB 0.01	ER 0.01	ER 0.00	BN 0.07	BN 0.01	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.01	AM 0.01	CB 0.31	CB 0.03	ER 0.01	ER 0.08	BN 0.54	BN 0.11
9. Tiring	IF 0.00	IF 0.00	OF 0.02	OF 0.01	HD 0.00	HD 0.00	AM 0.01	AM 0.02	CB 0.03	CB 0.09	ER 0.00	ER 0.01	BN 0.96	BN 0.49	IF 0.00	IF 0.00	OF 0.00	OF 0.00	HD 0.00	HD 0.00	AM 0.35	AM 0.91	CB 0.68	CB 0.64	ER 0.00	ER 0.02	BN 0.00	BN 0.00
10. Bothers me	IF 0.16	IF 0.04	OF 0.03	OF 0.17	HD 0.92	HD 0.95	AM 0.64	AM 0.82	CB 0.57	CB 0.08	ER 0.11	ER 0.62	BN 0.64	BN 0.14	IF 0.17	IF 0.23	OF 0.00	OF 0.01	HD 0.07	HD 0.06	AM 0.60	AM 1.00	CB 0.11	CB 0.09	ER 0.57	ER 0.43	BN 0.00	BN 0.00
11. Abrupt	IF 0.06	IF 0.00	OF 0.13	OF 0.00	HD 0.047	HD 0.00	AM 0.03	AM 0.00	CB 0.44	CB 0.01	ER 0.64	ER 0.16	BN 0.23	BN 0.48	IF 0.04	IF 0.03	OF 0.08	OF 0.14	HD 0.05	HD 0.13	AM 0.00	AM 0.00	CB 0.00	CB 0.00	ER 0.00	ER 0.00	BN 0.00	BN 0.00
12. Awkward	IF 0.11	IF 0.09	OF 0.73	OF 0.25	HD 0.08	HD 0.10	AM 0.61	AM 0.34	CB 0.01	CB 0.05	ER 0.62	ER 0.60	BN 0.14	BN 0.01	IF 0.40	IF 1.00	OF 0.11	OF 0.10	HD 0.29	HD 0.39	AM 0.26	AM 0.20	CB 0.00	CB 0.00	ER 0.31	ER 0.14	BN 0.00	BN 0.00

Table 2: (a) US and (b) Taiwan participant attitudes towards *SkinSwipe* gesture interaction. The presented data is compared against the baseline (i.e., mobile phone) values. Each cell indicates the level of agreement with a gesture interaction question (e.g., does this interaction look *normal*?) when the device is worn on a specific location (e.g., inner forearm (IF)) and the corresponding *p* value (the number shown below each body location). Similar with Table 1, the background of the corresponding cell is colored red (or grey) if the level of agreement towards the question is significantly higher (or lower) than that collected in the baseline case.

The back of neck (BN) looks significantly less public. The placement looks significantly more intimate on the inner forearm (IF), arm (AM) and collarbone (CB) for both genders, yet only significantly more intimate when worn on a female actor's outer forearm (OF), ear (ER), and back of neck (BN). All upper limb regions (i.e, inner forearm (IF), outer forearm (OF), hand (HD), arm (AM) were significantly more prone to accidental triggering. Placement on inner forearm (IF) and outer forearm (OF) looked significantly less bothering on a female actor, whereas the collarbone (CB) and back of neck (BN) looked significantly more bothering on a female actor. Both genders found the collarbone (CB) and back of neck (BN) to be significantly more awkward.

US/Taiwan Device Placement Attitude Comparison. We report on main observations comparing US and TW responses towards placement:

- The placement is significantly more conspicuous on all body locations for TW participants, but no significance was yielded for the US participants.
- Both US and TW participants reported placement on the inner forearm (IF), outer forearm (OF), and hand (HD) looked significantly easier to access.
- Both US and TW participants found the inner forearm (IF), arm (AM), and collarbone (CB) to look significantly more intimate.
- Both US and TW participants found all upper limb regions (i.e., inner forearm (IF), outer forearm (OF), hand (HD), and arm (AM)) to be significantly more prone to accidental triggering.
- Both TW and US participants found placement on the collarbone (CB) and back of neck (BN) to look significantly more awkward.

Gesture Interaction Attitudes (Table 2)

Table 2 shows the comparison of attitudes for *SkinSwipe* gestural interaction. The presented data is compared against baseline(i.e, mobile phone) values. We report only statistically significant results (p<0.05) for the purpose of readability.

Taiwan Participants (Table 2(b)). We report on Taiwanese participant response towards gesture interaction in Table 2(b), reading down the rows. For Taiwanese participants, interaction with *SkinSwipe* on all seven body locations looked significantly less normal, less natural, more silly, more weird and more cool. Interaction with the device looked significantly more easy-to-use for the inner forearm (IF), outer forearm

(OF), hand (HD), and ear (ER), but significantly less easy-to-use for the back of neck (BN). Interaction on all upper limb regions (i.e., inner forearm (IF), outer forearm (OF), hand (HD), and arm (AM)) were viewed as significantly more prone to accidental triggering. The interaction looked significantly more impolite on a female's collarbone (CB), whereas the back of neck (BN) looked significantly more tiring and bothering on both genders. Interactions on all locations except the outer forearm (OF) and hand (HD) were perceived as significantly more abrupt. The interaction also looked significantly more awkward on the collarbone (CB) and back of neck (BN).

US Participants (Table 2(a)). We report on US participant response towards gesture interaction in Table 2(a), reading down the rows. For US participants, interactions looked significantly less normal on all locations. The interactions appeared significantly less natural on the collarbone (CB), and back of neck (BN) for both genders, yet only significantly less natural for the female actor on the arm (AM). The back of hand (HD), collarbone (CB), and back of neck (BN) looked significantly more silly and more weird for both genders, yet only significantly more weird for the female actor on the arm (AM) and ear (ER). The inner forearm (IF) is significantly cooler for both genders, yet the outer forearm (OR) and ear (ER) is only significantly cooler for the male. The interaction is significantly more easy-to-use for the inner forearm(IF), outer forearm (OF), hand (HD), and ear (ER). Interaction on all upper limb regions (i.e., inner forearm (IF), outer forearm (OF), hand (HD), and arm (AM)) were viewed as significantly more prone to accidental triggering. The interaction appeared significantly less impolite when worn on a US female actor's collarbone (CB) and back of neck (BN). Interaction looked significantly less abrupt when worn on a US female's inner forearm (IF), outer forearm (OF), hand (HD), arm (AM), and collarbone (CB). The interaction was also significantly less abrupt when worn on a male actor's hand (HD) and arm (AM). However, when worn on a US male actor's collarbone (CB) and a US female actor's back of neck (BN), it looked significantly more awkward.

US/Taiwan Gesture Interaction Attitude Comparison. We report on main observations comparing US and TW responses towards gesture interaction:

- For both US and TW participants, interactions looked significantly less normal on all locations.
- For both US and TW participants, interaction on all upper limb regions (i.e., inner forearm (IF), outer forearm (OF), hand (HD), and arm (AM)) were viewed as significantly more prone to accidental triggering.

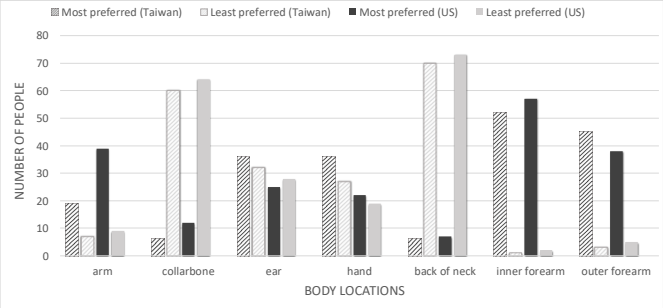


Figure 3: Number of the most/least preferred body locations responded by US and Taiwanese participants.

- The interaction appeared significantly less impolite when worn on a US female's collarbone (CB), yet significantly more impolite when worn on a Taiwanese female's collarbone (CB).

Followup Findings

The follow-up questionnaire uncovered further attitudes towards on-skin interfaces. The inner forearm arose as the most preferred location for both US and Taiwan participants (US: 57%, Taiwan: 52%) (darker bars in Figure 3). The second most preferred location for Americans is the arm (39%), with the outer forearm as a close third (38%). In Taiwan, however, the outer forearm was the second most popular location (45%), with the ear (36%) and hand (36%) at a tie for third. Americans found the inner forearm and arm to be in locations that are easy to use and easy to access. The inner forearm was preferred since it posed no limitation on clothing, and is "discreet." Beyond being easy to use, the arm was described by many Americans to be "cool." This might be explained by the arm being a popular tattoo location in the US [23]. Taiwanese participants held similar, positive viewpoints towards the inner forearm as their American counterparts, sharing the viewpoint that it mirrored wearing a smart watch or accessory. They, however, preferred the outer forearm, ear, and hand in place of the arm. Participants mentioned that clothing does not typically cover these body locations. The outer forearm and ear also resemble wearing a smartwatch or earpod.

Participants were also asked to explain their two least preferred body locations (lighter bars in Figure 3). Participants in Taiwan and the US both held a strong dislike for the back of neck (US: 70%, Taiwan: 73%) and the collarbone (US: 60%, Taiwan: 64%). Americans found the back of neck and collarbone "awkward," "unnatural," and "inconvenient for operation." Participants described the gesture interaction to be "prone to accidental triggering." Taiwanese participants were especially concerned with reaching to touch the back of the neck since this would expose the armpit area and appear impolite. Taiwanese participants also expressed the collarbone region was too close to private areas, especially for a

female. The swiping gesture was also viewed by some to be suggestive.

Participants were then asked to describe their ideal placement for wearing the *SkinSwipe* interface, not limited to those shown in the survey. Beyond the locations covered in our survey, behind the ear (13%) arose as an accessible location for Taiwanese participants. Many Taiwanese (7%) and American (9%) participants preferred to wear it where they wore a watch. The fingers (e.g., the thumb, finger joints) was also a preferred location for both Taiwanese (5%) and Americans (4%). A recurring reason for these locations is they often remain exposed regardless of clothing. Taiwanese participants also mentioned other locations, such as the face (e.g., dimples) (3%) or the torso (waist, nipples, belly) (4%). Some Taiwanese participants preferred textiles and not an on-skin device (3%).

Participants raised a range of concerns regarding the on-skin interface. For Americans, over half (55%) were concerned about health and safety, including potential harm to skin, allergic reactions, to exposure to radiation. Other concerns for Americans included user-friendliness (21%) and aesthetics (14%). For Taiwanese participants, the primary concern, raised by over one third (38%) of the participants, was the user-friendliness of the device, with an emphasis on "convenience." The functionality of the device was also of prime importance to Taiwanese participants (32%), including the type of gestures supported, wireless connectivity, to supported battery life. Participants also mentioned accidental triggering (27%), adhesion (i.e., is it waterproof? Does it hold under sweat?) (24%), health concerns (24%) and aesthetics (15%). In general, Taiwanese participants are more concerned with the performance and practical functions of the device itself, while US participants have greater health-related considerations. Another observation is that many Taiwanese participants (16%) mentioned being concerned about the perception of others, and not wanting to appear "stupid" or "embarrassing." They preferred a "low key" presentation. American participants did not raise this concern.

Perceived system usefulness (slightly useful, moderately useful, very useful) was rated at 68% for the US and 66% for Taiwan. Only 4% American participants, and 1% Taiwanese participants found it to be "very un-useful." 72% American participants would be "very willing," "moderately willing," or "slightly willing" to use the device, with only 1% indicating they are "very unwilling" to use the device. Similarly, 68% Taiwanese participants indicated they would be "very willing," "moderately willing," or "slightly willing" to use the device, with only 3% indicating they would be "very unwilling" to use the device. Perceived activity hindrance of using on-skin interfaces placement was compared with the baseline. Besides the hand, which yielded no significant difference, all other body locations are considered less hindering than a mobile phone baseline ($p \leq 0.01$). Participants were asked to rate the two most important system features. Options included: comfortable to wear, easy to apply and remove, doesn't make me look weird or awkward, can be moved between different body locations, is not very noticeable to others, can use without looking, doesn't interfere with movement, doesn't interfere with items worn on the body, easy to access, easy to operate, or other. Easy to operate (US: 46%, Taiwan: 48%), easy to access (US: 32%, Taiwan: 35%), and doesn't interfere with movement (US: 25%, Taiwan: 35%) emerged as the top features for both countries. The next most significant concerns then diverged into "can be moved between different body locations" for US (20%), and "doesn't make me look weird or awkward" for Taiwan (21%).

5 DISCUSSION AND DESIGN IMPLICATIONS

Results from our on-skin perception study (Table 1 & 2) show that placement and interaction on all body locations appeared significantly less normal, less natural, more silly, and more weird to Taiwanese participants. This result may imply that Taiwanese participants held more reservations, and therefore could be less accepting towards seeing on-skin interfaces used in public. Taiwanese participants also found device placement to be significantly more conspicuous on all body locations. Compared to their American counterparts, they also identified more body locations as significantly more private (i.e., inner forearm, collarbone, ear (female only)) and intimate (i.e., all placements except outer forearm (male)). Nevertheless, Taiwanese participants still found the devices to be cooler and more attractive than using a mobile phone for all body placements. On the contrary, US participants identified fewer locations as significantly less normal, less natural, more silly, and more weird compared to their Taiwanese counterparts. This result may imply that Americans found the on-skin interfaces to be more acceptable to be worn in public. US participants were also significantly more flexible towards seeing the on-skin interface worn on different body locations (i.e., very few placements are perceived as less public or more private).

Results also reveal that US participants exhibited more different gender preferences towards device placement or interaction. For example, placement on the arm looked significantly more easy to access, more private, and more weird only for the US male. The gestural interaction was viewed as more attractive on the outer forearm, and cooler on the hand and collarbone only for the US female actor. It may be helpful to factor in gender difference in device design, especially for cultures sensitive to such concerns. It could also be useful to integrate elements of end-user customizability to cater to individual preferences.

We also gained several insights from the follow-up questionnaire. Mirroring findings from the on-skin perception

study described in the start of this section, we found qualitative data on Taiwanese participant's strong affinity for a device that avoids making the user look "stupid" or "embarrassing." 16% Taiwanese mentioned they worried about others' perceptions towards the device. No Americans raised this concern. This result may be attributed to the culture in Taiwan, which embodies the Confucianist Han Chinese values of modesty and communal living. This result also echoes the findings of Profita et al. [20] for textile-based gestural interfaces, which found a strong preference of East Asian participants to avoid looking "weird" or "awkward." We do, however, observe Taiwanese participants preferring locations that are occupied by existing body-worn objects (e.g., the wrist: watch; ear: earrings, earpods). A possible explanation is that these existing objects serve as metaphors with which to understand and make sense of these emerging on-skin devices. The unfamiliarity of the on-skin device may also be "disguised" behind the familiarity of an existing object, so it stands out less in a public setting. To this end, there could be value to design initial form factors that occupy the locations or even embody the appearances of existing body-worn objects to increase acceptance.

Unlike clothing and accessories, on-skin interfaces are situated directly on the wearer's body, often covered by layers of clothing. This blockage by clothing was a common concern raised by participants. In describing their ideal location for wearing the on-skin interface, participants mentioned areas due to the fact they are typically not covered by any clothing (e.g., fingers, face). In describing the two most preferred body locations shown in the survey, "not covered by clothing" was a common reason listed by Taiwanese participants. To this end, there may be value in designing on-skin interfaces situated in locations not blocked by clothes for cultures sensitive to such concerns. However, we can see that Americans selected the arm as one of the top two preferred body locations, despite the location's propensity to be covered by sleeves. In such cases, it may be worthwhile to design in additional functionality for the on-skin device when covered by clothing to increase usability. For example, the on-skin device could be charged when covered by clothing through textile-integrated wireless inductive charging. Doing so also offers potential to miniaturize further the form factor of the on-skin device by offloading components to the clothing layer.

6 LIMITATIONS AND FUTURE WORK

Our study participants did not directly witness or engage in the social interaction, but only viewed a video. We were also only able to analyze participants' self-reported perceptions. Conducting in-the-wild future studies might reveal further insight and tensions for interactions.

We choose to focus on a single on-skin device and interaction modality (input). Doing so allowed us to reach more participants, and observe the effects of conditions around placement and interaction. It would be interesting to study variances in participant attitudes across different on-skin form factors, interaction modalities, a more comprehensive range of body locations, to demographic factors in future research.

7 CONCLUSION

In this paper, we presented a cross-cultural examination of the social perceptions towards an on-skin gestural interface. Our research suggests there is a shared affinity towards on-body placement in US and Taiwan for the inner forearm, with the ease to use and access as primary reasons. Our quantitative and qualitative analysis indicated that Taiwanese participants have more reservations towards seeing the device worn in public in comparison to their US counterparts, which may stem from cultural propensities. We are encouraged that the majority of participants found the *SkinSwipe* interface to be "useful" and they were "willing" to use the device. To the best of our knowledge, we contribute the first studies to shed light on societal perceptions towards on-skin interfaces through this paper. As interface progress towards intrinsic human augmentation, we seek to uncover user attitudes to offer insight for designing on-skin interfaces which may be accepted for public use.

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