WEARABLE TACTUAL COMMUNICATORS: DESIGNING PRODUCTS WITH TECHNOLOGY-MEDIATED TOUCH

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ABSTRACT
In some situations, it is not possible or desirable for communications to take place through voice- or screen-based interaction. People may want to act discreetly around other people; it may not be physically possible to interact with a screen-based product; or it may be inappropriate or ineffective to talk out loud. Furthermore, with the challenges of the COVID-19 pandemic, product touch has been discouraged. In the circumstances, alternative means of communication can be made using technologies that mediate touch. This paper reports on an eight-week graduate industrial design project that required students to explore the sense of touch in the context of user-product-user communication. The aim was for students to learn how a product user interface (UI) can extend beyond the conventional visual and audible modalities, into the relatively under-explored area of touch sensations. Working in pairs, students made research and generated product concepts for communication scenarios that they foresaw would benefit from technology-mediated touch. The result was eight diverse scenario and product solutions that make use of passive touch sensations: some focused on the communication of instructions, whilst others evoked meanings. Learning was demonstrated through the diversity in outcomes, with students proposing unconventional forms of interaction where touch is the primary modality. The study empowered students to showcase innovative uses of technology-mediated touch in product design.

Keywords: Product design, touch, interaction, UI, wearables

1 INTRODUCTION

In our daily interactions with products, the conventional product evaluation process for people with no sensory impairment is for visual experience to take the lead, shortly followed by tactual and other multisensory experience as interaction takes place. Vision is dominant in human information processing and cognition [1]. It is therefore no surprise that the visual domain of product design is at the forefront of designers' decision-making, leaving the tactual domain – as well as other sensory modalities – relatively under-researched [2].

The work presented in this paper was carried out as part of the authors' research agenda investigating aspects of product touch, tactility, surface texturization and user experience (UX). The research agenda aims to generate informative and inspirational exemplars for product design and innovation. The specific project reported in this paper, 'wearable tactual communicators', explored the problem and solution spaces related to the effective design of user-product-user communication through the medium of touch. For example, in some situations it is not possible or desirable for communications between people to take place through voice or screen-based interaction. People may wish to act discreetly around other people; it may not be physically possible to interact with a screen-based product; or it may be inappropriate or ineffective to talk out loud. For such circumstances, alternative means of communication using technologies that mediate touch can be speculated. Aside from generating exemplars for product design, the 'wearable tactual communicators' project had the pedagogical goal of encouraging students to learn how technology-mediated touch can push product user interface (UI) design beyond conventional visual and audible modalities.

2 INTERACTION AND DESIGNING FOR TOUCH

The sense of touch is central to the full experience of many everyday products. There are relatively few products that we look at, or we listen to, for which we do not physically interact. Touch is in many ways

a special sense: it is differentiated from visual and audible modalities because of the complexity of the sensorial information that is involved. Whereas sight is achieved through the eyes sensing light frequencies, and hearing is achieved through the ears sensing sound frequencies, touch is not bound physically to any single sensory organ. Touch is a sensation of the skin and muscle, and as such can be achieved all over the body. Furthermore, touch comprises the discrimination of multiple tactual qualities of things, including softness, texture, and temperature. Touch is considered as active/passive or static/dynamic, depending on the circumstances in which the sensations are created [3], [4].
Passive touch involves an object being placed onto or rubbed against a person's skin. Active touch, by contrast, involves a person exploring an object, often through grasp or dexterous fingertip movements. Touch is most noticeable when it is dynamic; that is, when the stimulation continually changes [5]. This contrasts with static touch, which gives an initial sensation but then goes unnoticed.
Touch is a vital contributor to interpersonal communication. As Sonneveld & Schifferstein [3] state, "touch is […] often considered as our most social sense. Interpersonal touch tells us whether we are safe, cared for and have value…". Different touch types, such as public touch or loving touch, have distinct characteristics [6], whilst emotions and meanings are known to be strongly evoked through touch [7], [8].
Designers need to be aware of factors that influence positive appraisal of touch (e.g., pleasant, comfortable, reassuring). Essick et al. [9] made a quantitative investigation of the tactual pleasantness of an object when passively rubbed on skin at different body locations, through a controlled mechanical experiment set-up. Their work confirmed several assumptions about the variables affecting sensitivity to – and pleasantness from – passive touch sensations: gender, context, stimuli surface qualities, body area, and the degree of surface pressure from low (pleasant) to high (painful).
Marieke Sonneveld laid foundations for 'designing for touch' by bringing the various mentioned principles together. Her 'Tactual Experience Model', originally developed in Dutch [10] and translated into English [11], is shown in Figure 1. It usefully demonstrates the relations between underlying factors in touch experience, by contrasting product and user (human) perspectives. The model was used as a basis for our students' learning on how to enhance touch experiences from products.

3 DESIGN PROCESS FOR WEARABLE TACTUAL COMMUNICATORS

The 'wearable tactual communicators' project was carried by Industrial Design MSc and PhD students over eight weeks of the 'ID535 Design for Interaction' course Middle East Technical University. Students worked in eight pairs to design a physical product (and, optionally, an accompanying app) that provided effective interpersonal communication by passive touch, as an alternative to vision and sound. Prior to the project, students took seven weeks of foundation classes in design for interaction (D4I) and UX [12].

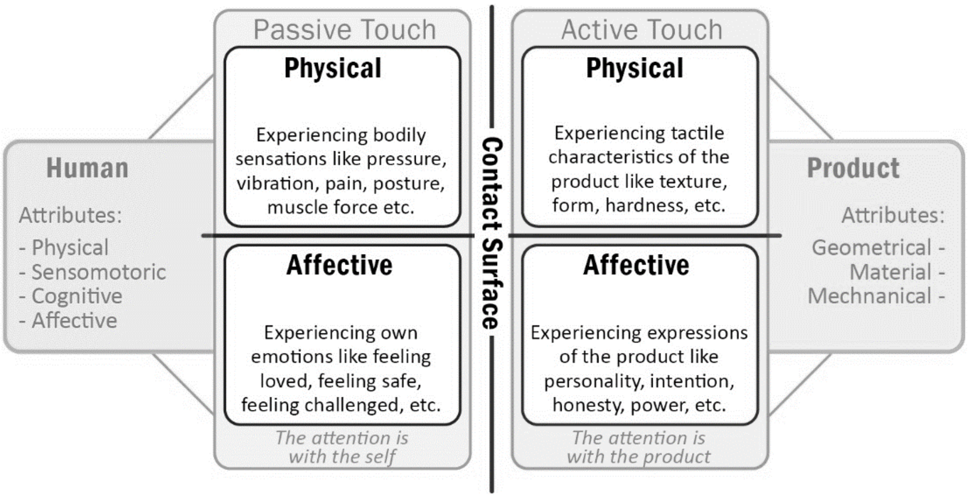

Figure 1. Tactual Experience Model (Sonneveld, 2010); translated by Fennis (2012) and revisualized by the authors

Despite focusing on the UI and interaction, final design proposals were required to show good attention to product styling, materials, finishes and overall visual attractiveness. However, compared with undergraduate studio projects that are typically longer and with greater scope, the level of technical resolution expected was less, attention to materialization was reduced, and market/commercial justifications were not requested. Students were provided with articles and book chapters to read, to elevate their general knowledge in touch and design.

3.1 Project Stages

The project was managed across seven stages, requiring students to carry out design research, ideation, and technological reviews, whilst developing a heightened awareness of product touch sensations.

3.1.1 Scenario building

Students were asked to generate a minimum of five scenarios (contexts of use) where tactual person-to-person interaction via a product might be effective or desirable. Storytelling was requested to bring the scenarios to life, based on four questions: Who is communicating with whom? Why and what are they communicating? Where are they? When is this happening?

3.1.2 Sensitization activity

Students were asked to bring to class various products possessing pronounced surface textures, surface form features or material tactility, which deliver noticeable touch sensations. Students became sensitized to passive touch by exploring the tactual sensations of classmates' products at various locations on the body (e.g., fingers, forearm, neck, head). In their project pairs, students took turns to be the provider and receiver of passive touch. Subsequently, they were asked to contemplate how touch sensations might be used as a communication language, aside from pleasantness or comfort.

3.1.3 Briefing on technical possibilities

A PhD student working on touch and design briefed students on the various technologies that can make technology-mediated touch possible. Many of the technologies are at an early or prototypical stage of development. As well as becoming knowledgeable about the technologies, students were expected to identify which were most suited to their own project. The briefing covered: (i) haptic feedback technologies (sometimes referred to as haptic rendering) such as vibrotactile actuators, tactile surfacing, thermal changing materials, shape changing materials, and force feedback; and (ii) haptic sensing technologies, such as conductive fabric and force sensors. Students were additionally briefed on common wireless communication technologies (e.g., Bluetooth 4.0, Wi-Fi 802.11n and 4.5G/LTE GSM) as well as their specifications relevant to product design.

3.1.4 Interaction vision and ideation

Following Pasman et al. [13], we directed students through the combination of a design goal (as mentioned in 3.1.1, responding to the question 'why communicate?') and an interaction vision (responding to the questions 'how to interact?' and 'what style/qualities of interaction?'). The interaction vision was prepared as a few words or a short phrase, using carefully chosen adjectives/adverbs so as to be inspiring but also to avoid preconceived ideas. Pasman et al. [13] provide general advice on differentiating design goals and interaction visions, e.g., "The *goal* was to design an inspiring lunch experience for customers of the university canteen, while the *interaction vision* was stated as 'Refreshing Openness'." Students were given the option to also create an A3 inspiration board comprising images of products, surfaces, materials, people, places and interactions that possessed qualities they found relevant to their interaction vision, or which illustrated the vision directly. Initial ideas were sketched, attending to system, service (app), product, interaction and UX requirements for the tactual communicator. Ideation also included a technical appraisal for the kinds of touch sensation that was sought (applying knowledge from 3.1.3), as well as continual scenario iteration. Furthermore, students developed arguments for the specific tactual messages that would be relevant to their scenario and worked on mapping those messages to specific touch sensations, creating a touch vocabulary for their product. The authors gave several design critiques through this stage.

3.1.5 Interim submission

At this stage, students presented their in-progress product design, focusing on tactual messages/language, storyboard of interaction and a draft user guide.

3.1.6 Concept development

The authors gave a further round of design critiques at this stage, with the expectation that students would then be able to interpret their interaction vision into well-defined interaction steps (=what to do) and actions (=how to achieve it), within an overall coherent product design.

3.1.7 Final submission

At the final stage, students prepared and presented a poster, factsheet, and design sketchbook. Some students used initiative to also prepare CAD animations, videos and mock-ups.

4 PROJECT OUTCOMES AND DISCUSSION

The project resulted in eight diverse scenario and product proposals. Some proposals used passive touch sensations to communicate information or instructions (thereby prompting a behavioural/action response), whereas others used passive touch sensations to arouse visceral feelings and evoke meanings (see Figure 2). As a reminder, we did not ask students to exclusively use tactility to replace existing visual or audible feedback. Rather, we encouraged exploration of scenarios in which passive touch can create new interaction possibilities or overcome long-standing interaction problems tied to reliance on visual and audible modalities. A cross-comparison of the key variables across the eight design proposals is provided in Figure 3.

The focus on tactility became a driver for creativity, taking students out of their 'comfort zone' when designing for interaction. Stage 2 of the project – the sensitization activity – was highly valuable for students to 'tune in' to the possibilities of communicating via touch. By reciprocating between the giver and the receiver of passive touch, students engaged in a form of active learning about effective tactual communication. They learnt through practice that tactual communication relies on people's ability to (a) differentiate the feeling of different passive touch sensations, and then (b) give meaning to each sensation. For effective communication, each tactual sensation (message) must be clearly distinguishable and not confused with other tactual sensations offered by the product. These observations were first made during the sensitization activity but became practically relevant once students started to build their interaction vision and generate product ideas at stage 4 of the project.

Since the reported work was completed within a limited timeframe of eight weeks, the design proposals were requested to be communicated through storyboards. The inherent restrictions are acknowledged: storyboards illustrate steps and actions but do not communicate the qualitative experience during interaction very well. As a surrogate, students described their intended user experiences by referring to tactual sensations of everyday products. Educators working in D4I recognize this as a persistent pedagogical challenge: how to bring an intended interaction 'to life'. As a visual communication medium, storyboards are excellent for planning and narrating interactions step-by-step. However, their main weakness is being unable to evoke the feelings or meanings that arise from physical interaction. Therefore, given more time, the use of physical models of various fidelity can be recommended for role-play (at stage 4), whilst tactual experience prototypes may be created for the final submission, allowing evaluation of intended tactile sensations. The creation of experience prototypes would require students to utilize design-and-make skills, inevitably overlapping with skills in interactive prototyping and preparation for 3D printing.

In the absence of experience prototypes, three evaluation criteria suited to the assessment of storyboards were defined for the project: detail of thought in defining user-product interaction; clarity of argument for how the final design concept fits to an intended usage scenario; and technical feasibility for delivering tactual messages within the proposed form-factor.

5 CONCLUSIONS

The project outcomes showed students successfully learned how tactual interaction can be used to create product interfaces for scenarios in which visual and audible modalities are found inadequate or undesirable. In this regard, the project was able to extend 'design for interaction' teaching and learning beyond conventional audio-visual UI. Students learned that tactual communication has multiple dimensions, which demand a systematic approach to design. For success, there must be a clear definition of the kind of tactual sensations to be achieved (intensity, frequency, body location, etc.). Then, a system must be designed whereby the intended sensations are perceptible and technically achievable. Finally, an appropriate mapping must be achieved between tactual sensations and intended messages (whether instructional or affective). This last point was pedagogically the hardest to achieve. It required students to understand that affect and meaning arising from touch are contextually bounded and can be different for different people. Students working on the 'wearable tactual communicator' project were guided through a systematic approach, not for lack of confidence in their creative abilities, but to provide a 'helping hand' across what was for all students very unfamiliar territory.

Learning about tactual interaction modalities, and putting them into practice through a design project, is considered a valuable experience for students whose future professional roles may be to design innovative UIs and effective interactions for new generations of product. The project contributed convincing solutions for how technology-mediated passive touch can be used as a language of communication between products and people; such product examples and analysis are not prevalent in literature. In this way, the project empowered students to showcase innovative uses of technology-mediated touch in product design. Experiences during the COVID-19 pandemic, which arrived after the work reported in this paper, have shown people's yearning for social touch and the importance of a physical connection in interpersonal relations. Wearable tactual communicators as exemplified in this paper may also be developed to help people overcome touch deficits, for example through technology-mediated remote social touch that can bring loved ones and friends together.

Figure 2. Summary of each wearable tactual communicator proposal

Application	Product	Scenario	Rationale	Passive Touch Trigger	Passive Touch Receipt
Informational or Affective? (I or A)	What is the product name?	Who is communicating with whom?	Why are they communicating?	What input is required?	Which haptic feedback technology?
I	Dyad	Alpine climber and belayer (1-to-1)	Keep in contact and updated when out of sight or shouting distance	Controls and head movements	Electro-vibration
I	Boomerang	Bedbound patient and caregiver (1-to-1)	Respond to patient's various needs	Controls	Matrix of electro-magnetic actuators under textile
I	AeroCom	Aircraft passengers, attendants and pilots (network)	Make requests, serve passengers and give instructions	Touchscreen gestures or icon selection	Pneumatic shape memory actuators; vibration motor
I	Ignis+Tactio	Firefighter teams (network)	Report critical discoveries during firefighting and rescue	Touchpad gestures	Vibration actuators
A	Wellmate	Best buddies (1-to-1)	Encourage cessation of bad or unwanted habits	Touchscreen gestures or icon selection	Vibrating and inflating soft silicone actuators
A	AffiniSleeve	Prison inmate and visitor (1-to-1)	Help express positive and negative emotions	Touchpad gestures	Matrix of textile pockets activated by air pressure
A	Sentio'es	Stage artist and audience (1-to-many)	Increase engagement in live theatrical performance	Touchpad gestures	Vibration motor; electro-magnetic actuators
A	Apart	Partners in long distance relationships (1-to-1)	Emphasize togetherness through lost sense of touch	Touchscreen or app icon selection	Texture-changing soft robotic skin

Figure 3. Key variables across eight proposals

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