FabTouch: A Tool to Enable Communication and Design of Tactile and Affective Fabric Experiences

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Figure 1: *Left*: Fabric tactile exploration of nine different cotton fabrics; *Center*: Users' description of their tactile and affective fabric experiences; *Right*: FabTouch tool designed to enable communication and design of fabric experiences.

ABSTRACT

The tactile experience of fabric is not only a sensory experience but also an affective one. Our choice of fabric products, like clothing, is often based on how they feel. Effectively communicating such experiences is crucial for designing tactile fabric experiences. However, there remains a lack of comprehensive understanding of the fabric tactile and affective experiences, preventing the development of tools to facilitate the communication of these experiences. In this paper, we examine the fabric experiences of 27 participants towards nine cotton samples. We combine qualitative and quantitative methods to create FabTouch, a novel tool to facilitate a dialogue in the design of fabric experiences. We found six phases of fabric touch experiences including fabric touch responses, sensory associations, and emotional responses. Initial feedback from designers suggested that FabTouch could enrich design processes both in practice and in education and can create inspiration for physical and digital design explorations.

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CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**; **User studies**.

KEYWORDS

Fabric; Touch; Tactile Experiences: Affective Responses; Diachronic and Synchronic Experiential Mapping; Multisensory Experiences.

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1 INTRODUCTION

Consumers and designers often make initial judgments about a fabric's quality (such as a garment) based on how it feels to them or, in other words, their tactile perception and affective responses [29, 37, 43]. The tactile and affective responses associated with touching an object can have a profound impact on human perception and can result in purchasing decisions [10, 38, 55]. For example, Essick et al. [10] revealed that the frequency of touch for different fabrics reliably predicted their ratings of pleasantness. These tactile and affective perceptions of fabric and their subsequent influences on behaviour are essential to consider when designing interactive systems for fabric in the digital realm. However, developing interactive digital experiences for fabrics currently presents a number of challenges, including the lack of tools for communicating the tactile and affective experiences of fabric between designers, users, and developers [8, 30, 45]. This is primarily due to a lack of comprehensive understanding of the temporal fabric experiences concerning both tactile and affective aspects [1, 8, 30, 31, 37, 45]. Moreover, the user experience and current expert knowledge of these experiences have yet to be thoroughly investigated, limiting the ability of designers and technology developers to communicate them to create innovative digital fabric experiences [8, 45].

In response to these aforementioned gaps, this paper aimed to understand users' tactile and affective experiences towards fabrics, by applying a mixed-methods approach. A combination of Micro-Phenomenological Interviews (MPI) and quantitative methods (questionnaires) was employed in the study. MPI helps to uncover how an experience unfolds over time (diachronic structure) and their specific experiential characteristics (synchronic structure) [30, 36]. Hence, our study focused specifically on the temporal and experiential mapping of users' fabric experiences [8, 30, 45], taking into consideration prior research on textile materials [3, 39] and tactile perceptions of surface texture [17, 32, 55, 56]. Both diachronic and synchronic analyses explore the fabric touch experiences of 9 cotton fabrics in 27 participants. The diachronic structure provided insights into how participants' tactile and affective experiences unfolded over time, while the synchronic structure provided insights into the specific configuration of those experiences.

We identified a total of 6 overarching categories and 23 subcategories from all the expressions of the users representing the diachronic and synchronic structure of the users' fabric tactile experiences. Each of those categories was then described in detail with references to participants' expressions. We cross-validated these interview results with the results from the questionnaires, to enrich our understanding of the affective and tactile fabric experiences. Touching fabrics brings to mind associations with beloved objects, can make us emotional, and connect us to past memories. The richness of fabric tactile experiences lies in how we express it: "...I feel kind of good after touching that fabric, it makes me... a little bit emotional actually... I am missing my mom. Okay, it makes me emotional" [P011, F2]. This is only one excerpt from over 2945 participants expressions we collected in our study, demonstrating that fabric tactile experiences are much more than "textile handling", where only objective measurements of fabric properties are considered; and goes beyond perceptual information derived from surface texture.

Users' fabric tactile experiences include a wide range of tactile and affective responses which are often overlooked in design processes. By harnessing this richness, we contribute to the understanding of users' fabric tactile and affective experiences and demonstrate how those experiences unfold over time through extracting the diachronic and synchronic structure (6 overarching and 23 subcategories). Having identified these categories, we developed FabTouch, which is a tool that represents user-derived tactile and affective experiences. The aim of this tool is to enable a dialogue about these experiences that can lead to innovative ideas, for example, during the design ideation process. FabTouch can provide a reference point for communicating design ideas between designers coming from different backgrounds (e.g. tactile interaction and fashion/textile designers), and between designers and users.

2 RELATED WORK

The tactile perception of fabrics affects consumer choices and the technical decisions of fabric manufacturers [49]. Consumers and designers often select fabric products, such as clothes and blankets, based on how the fabric feels. These tactile and affective responses of fabrics are discussed in both textile material research and perceptual research. In textile material research, tactile properties of fabrics are often referred to as the handling of fabric, also known as the "textile hand" or referred to as "textile handling" [23, 38]. These studies consider a fabric's tactile perceptions through objectively measuring the fabric's physical (thickness, mass per unit area), mechanical (extensibility, bending properties, shear), surface (compression properties, friction, surface irregularities), and thermal (conductivity) properties [3, 11, 39]. In contrast to this focus on fabric properties, prior perceptual research has been primarily concerned with fabric tactile perception of the surface texture. Studies in this field emphasize the presence of a semantically multilayered and multidimensional informational system that corresponds to human tactile perception [17, 28, 32, 41, 55].

In the following section, we provide a brief overview of current studies in fabric material, tactile perceptual research and affective responses of fabric experiences, all of which are relevant to situating our study contribution.

2.1 Textile Handling

Fabric is a type of textile material that is used to fabricate finished products, such as jackets and trousers. Textile material studies have suggested that how people handle fabric is often determined by the properties of the fabric and how comfortable the fabric is felt subjectively. This evaluation process is often carried out using a subjective method known as "textile handling" [3, 11, 23, 39]. Textile handling is concerned with how the fabric is touched and bent with the fingers and then stretched slightly with the hand [23]. Often, when experts assess the touch experience with their hands, they pay particular attention to tactile perceptions, by subjectively evaluating roughness, smoothness, harshness, pliability, thickness, and so on [3, 11]. The subjective judgements of experts can then be objectively measured by assessing the fabric's physical properties (such as thickness, mass per unit area), mechanical properties (extensibility, bending properties, shear), surface properties (compression, friction, surface irregularity) and thermal properties (conductivity) [3, 11, 39]. These objective measurements of fabrics have been used to describe fabric tactile experiences, which are referred to as "textile hand". For the purpose of evaluating "textile hand", a variety of systems have been designed, including the Kawabata Evaluation System for Fabric (KEF-F), Fabric Assurance by Simple Testing System (SiroFAST), and Fabric Touch Tester (FTT) [3, 7, 22, 23]. Even though the objective measurements of fabrics and textile handling are well known in the design and textiles research fields, the users' subjective tactile experience and how it relates to the affective responses are widely neglected [3, 39]. There are however tactile perceptual studies we can build on.

Table 1: Summary table of the studies on tactile perception dimensions of surface textures.

Author	Year	Material	Dimension1	Dimension2	Dimension3	Dimension4	Dimension5	Modality	Reference
Yoshida	1968	50 mixed materials	Heaviness	Smoothness/Hardness	Visual/tactile impression	-	-	Visual and free hand exploration	[32, 55]
Yoshida	1968	25 mixed materials	Hard/soft	Cold/warm	Moist/dry (smoothness)	Hard/soft	-	Visual and free hand exploration	[32, 55]
Hollins	1993	17 mixed materials	Smoothness	Hardness	Springness	-	-	Tactile stimuli on index finger tip only	[17, 32]
Hollins	2000	17 mixed materials	Rough/smooth	Warm/cold	Sticky/slippery	Hard/soft	-	Tactile stimuli on index finger tip only	[18, 32]
Picard	2003	24 car seats materials	Soft/hardness	Thin/hardness	Soft/harsh	Pleasantness	-	Tactile stimuli with lateral hand movements	[32, 41]
Picard	2006	24 car seats materials	Soft/hardness	Thin/hardness	Relief	-	-	Visual and tactile stimuli with lateral hand movements	[32, 40]
Lyne	1984	8 tissues and paper towels	Hard/soft	Embossed (roughness)	-	-	-	Tactile stimuli	[5, 32]
Soufflet	2004	26 fabrics	Rough/smooth	warm/cold	-	-	-	Blind test with free hand exploration	[32, 49]
Shirado	2005	20 mixed materials	Rough/smooth	Warm/cold	Moist/dry	Hard/soft	-	Tactile stimuli	[32, 47]
Gescheider	2005	7 raised dots	Macro roughness	Rough/smooth	Fine roughness	-	-	Tactile stimuli	[14, 32]
Guest	2011	5 fabrics	Rough/smooth	Moist/dry	Hard/soft	-	-	Tactile stimuli	[15, 32]
Yoshioka	2007	16 mixed materials	Hard/soft	Rough/smooth	Oily	-	-	Tactile stimuli	[32, 56]
Drewing	2017	27 mixed materials	Roughness	Fluidity	Deformability	Fibrousness	Heaviness	Tactile stimuli	[9]

2.2 Tactile Perception of Fabrics

In contrast to textile material studies, tactile perception studies (which originate in psychology) are often concerned with the tactile perceptions generated by the surface texture touch sensation of an object [17, 41, 55] and it's related affective responses. The literature emphasizes the richness of a semantically multilayered and multidimensional information system and affective responses that correspond with the perception of cutaneous tactile perception [17, 28, 32, 41, 55]. Drewing et al. [9] showed that tactile sensations of roughness, fluidity, and deformability are significantly associated with three primary emotional dimensions, arousal, valence, and dominance [9]. It should be noted that despite these promising results, within this field of textile materials research, tactile responses are considered to be the primary focus rather than a deeper exploration of the associated affective responses [28, 32]. A summary of the most relevant research on tactile perceptions of surface textures, including fabrics, can be found in Table 1. A wide range of tactile dimensions are reported in these studies, including roughness, compression, warmth, silkiness, and material characteristics, but very few emotional dimensions are reported [32].

Although different studies have attempted to explain the dimensional structure of these tactile perceptions of surface texture, the conclusions have not always been consistent. Inconsistencies often persist in materials selection, criteria setting, and research methods [32]. A major reason for dissimilarities is the different materials and adjectives used to evaluate the tactile perception of the surface textures [32, 49]. As a result of these inconsistencies, it is often difficult to capture the tactile experiences associated with specific surface textures, such as fabric surface texture. A lack of understanding still exists regarding the tactile dimensions of fabric surface texture and its effect on the overall fabric touch experience.

2.3 Towards Designing Affective Textile Experiences

Even though tactile perception is an important aspect of fabrics, everyday tactile experiences with fabrics are also affective in nature. It has been found that when people touch an object it can elicit an affective response (e.g. pleasant or unpleasant reaction) and activates the brain regions associated with emotions (e.g., the limbic system) more than those associated with sensory responses [46]. Singh et al. [48] have also demonstrated a similar result by using tactile caressing of fabrics. Their result suggested that there is a difference between physical responses to different fabrics and higher-order emotional responses (valence) [48].

In the field of Human-Computer Interaction, textiles, as well as their tactile and affective responses, attract considerable attention [1, 20, 24, 25, 33, 43]. For example, the work by Ono et al. [33] presented a touch-sensitive fabric system that detects specific movements and pressures within a compact area through the use of a touch-sensitive fabric system. Huisman et al. [20] developed a tactile sleeve that uses three vibration motors to display six emotions, identified various types of touch associated with different emotions (e.g., stroking for love, squeezing for fear). A more recent study conducted by Kim et al. [24] demonstrated a knitted tactile interfaces that deliver expressive tactile feedback on the skin surface. The research conducted by Price et al. [43] examined dynamic haptic touch and presented a system called Tactile Emoticon, comprising a pair of remotely connected mitts, allowing users in various locations to communicate through tactile messages, orchestrating the duration and level of three haptic sensations: vibrations, pressure and temperatures. All those studies, however, remain focused on mechanical or electrical interactions with bodies or environments rather than investigating the users' tactile and affective experiences. Among those studies, only a few of them examined touch perception or tactile experiences with textiles. Atkinson et al. [1], however, has proposed three levels of tactile experiences to capture experiences with textiles. The author present a series of case studies that "attempts to relate the perceptions of experts to consumers, enabling them to communicate via a shared understanding of the tactile properties of textiles" [1]. As a result, they proposed that physical properties, perception space, and communication of experiences should be considered when communicating textile experiences digitally, such as for interaction design for touch screen devices. Despite the fact that they presented a design framework for communicating textile experiences, they did not explore the tactile and affective responses of users to textiles in detail.

Even though efforts have been made to facilitate the exchange of textile experiences between experts and designers, there is still a lack of a thorough understanding of users' fabric tactile and affective responses [12, 44], which, in turn, prevents the development of tools that would facilitate such communications between users and professionals.

3 USER STUDY

A number of studies have examined fabric properties and tactile perception, but affective responses to fabrics are still widely unexplored. Here, we examine users' fabric tactile and affective experiences through combining Micro-Phenomenological Interviews (MPI) with questionnaires on tactile perception and emotional responses to a selection of nine cotton fabrics. The study was approved by the local University Ethics Committee (approval number anonymised). All participants provided written informed consent before taking part in the study.

3.1 Selection of Fabric Samples

Nine different cotton fabrics were studied (see Figure 2, I), including *F1*-Heavy Drill, *F2*-Flannel, *F3*-Buckram, *F4*-Organza, *F5*-Velvet, *F6*-Voile, *F7*-Calico, *F8*-Muslin, *F9*-Twill. All fabric samples were made from 100% cotton. Cotton accounts for 35% of the world's fabric consumption and is one of the most commonly used natural fabrics [19]. Moreover, many of us are familiar with cotton, since it is a fabric commonly found in everyday clothing, such as jeans (for example, heavy drill fabric), shirts (flannel), and dresses (voile fabric). Furthermore, cotton offers a variety of different textures to be explored with regards to our study aim. This selection was made based on the "textile hand" evaluation reported by Atkinson et al. [1], which asked textile experts to select materials that are representative of a wide range of tactile experiences. For example, buckram fabric were described to represent the surface texture of being "rough" and voile fabric described to represent the surface texture of being "thin". These differences in the surface texture allowed for a variety of touch experiences also in our study.

3.2 Study Setup and Procedure

Each of the nine cotton fabrics was cut into squares of 20x20cm and mounted on white A3 cardboard with the top corners stitched to the cardboard (see Figure 2, II). Since fabric color plays a significant role in "tactile impressions" [34, 55], the fabrics were inserted into the bottom of a white box with a curtain facing participants to obscure their visual perception of the fabric (see Figure 2, III).

The whole study lasted no longer than 1.5 hours and consisted of three main parts (as show in Figure 3).

Part 1 Familiarisation: Participants explored one fabric sample (not used in part 2) inside the box using their dominant hand. Then they were guided through a short warm-up interview session. This was useful to familiarise participants with the setup, to be comfortable, and the MPI interview questioning style (the how and what of the experience, see further details in section 3.3.1) [36].

Part 2 Fabric exploration and interviews: Participants were presented with a total of three fabric samples (each presented one by one). They were asked to again put their dominant hand into the box (as shown in Figure 2, III) and then explore the fabric for one minute (kept consistent across all participants). Following the fabric exploration, a short 10 minutes MPI interview took place. This process was repeated for each of the three fabrics. The selection and order of the fabric samples was randomised across participants. Please note that only three out of the overall nine fabric samples were used to keep the study duration within 1.5 hours and avoid fatigue for both the participant and researcher part. Participants however assessed all nine fabric samples in the final part 3.

Part 3 Questionnaires: After a short break, participants were asked to complete the two questionnaires (tactile perception and emotional responses questionnaires - see details in section 3.3) for all of the nine fabric samples. Each fabric sample was placed one by one inside the box for one minute (same procedure as in Part 2), for the participant to explore and to then complete the questionnaires. The order of the fabric samples was randomised across participants.

3.3 Mixed Method Approach

To investigate tactile and affective fabric experiences we combined qualitative (Micro-Phenomenological Interview) and quantitative (questionnaire) methods.

3.3.1 *The Micro-Phenomenological Interview (MPI) technique*.

The MPI technique combines psychological and phenomenological perspectives to elicit verbalisations of subjective experiences [27, 30, 36]. MPI is a form of guided introspection that seeks first-person accounts by using language, sensory interpretations, and imagery derived from neurolinguistic programming which is used to search for evocative first-person narratives [49]. MPI interviews are especially valuable due to the question phrasing, which encourages participants to express their experiences with respect to a specific moment. A typical MPI interview would ask questions of "how" and "what" of the experience, instead of asking "why" questions [36] to avoid explanations or abstract considerations. Participants are encouraged to continue talking about the experiential aspects of the moment without relying on rational explanations and comments [30]. Typical questions like these are not intended to evoke thoughts or feelings, but rather explore the development of an experience over time (the *"Diachronic"* dimension), and the facets (specific configuration) of an experience at a particular time (the *"Synchronic"* dimension) [37].

The goal of questions related to the diachronic structure is to understand how the description of an experience unfolds over time (using questions like "What happens after you touched the fabric?" and "What do you perceive next?). With respect to the synchronic structure of an experience, the participant is questioned about a particular moment (using questions like "At the moment when you touch the fabric how does it feel?" or "What else comes to your mind at that moment?"). Thereby, the specific configuration of the experiential (tactile and affective) sensation at a given moment of time can be investigated. In this paper, we developed the interview questions in accordance with this interviewing technique. For instance we asked: *"Take your time to think back to the moment when I asked you to explore the fabric. What happens first?"*. This

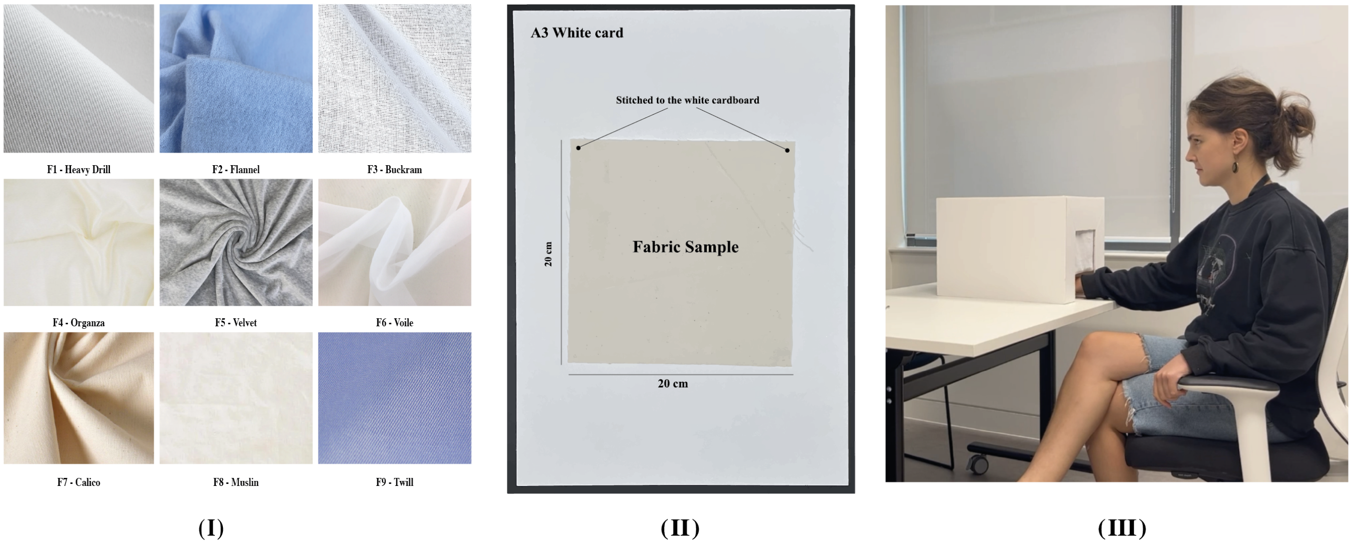


Figure 2: (I) Illustration of the nine selected cotton fabrics (*F*-Heavy Drill, *F2*-Flannel, *F3*-Buckram, *F4*-Organza, *F5*-Velvet, *F6*-Voile, *F7*-Calico, *F8*-Muslin, *F9*-Twill) used in the user study; (II) Each fabric was cut into 20cm*20cm squares and mounted on A3 white cardboard with the top corners stitched to the cardboard; (III) The study setup where the participant would put the hand inside the box to explore the different fabric samples.

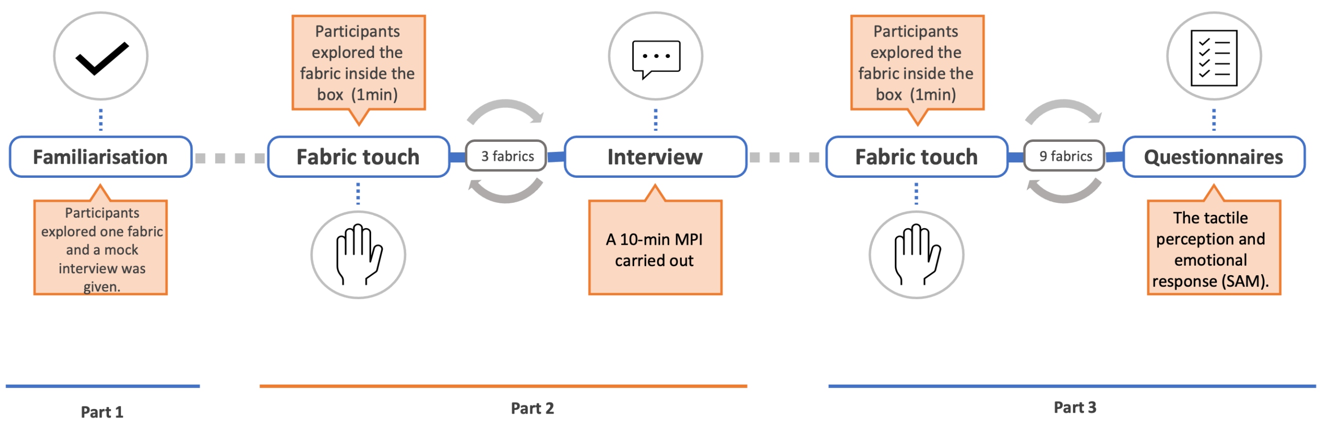


Figure 3: Overview of the three main parts in the user study: from an initial familiarisation (Part 1), fabric touch exploration and interviews (Part 2), and a final assessment of the fabric tactile and affective experiences using questionnaires (Part 3).

is a *"diachronic"* question that focuses on the temporal unfolding of the experience, starting from the action of the user. Based on the answer from the participant, the interviewer follows up with another diachronic question *"What happens next?"* or proceeds with a *"synchronic"* question, such as *"How do you describe this feeling when touching the material with your fingertips/palm?"* in order to deepen the insights on the affective responses to the described experience. A full list of the guiding questions used in our study can be found in the Supplementary Material. Compared to other interview methods using an open questioning approach, this technique is non-inductive but directive, because it keeps the participant focused on the experience, which is explored, without inducing any content. The focus of the MPI technique is on the structure of the experience that is investigated.

MPI interviews have been increasingly used within HCI research, especially in user experience studies [45] to uncover a more fine-grained understanding of sensory experiences (e.g. tactile experiences [8, 30]), textile experiences [37]), which makes it a valuable approach for our study aim.

3.3.2 *Tactile perception and emotional responses questionnaires*.

To extend the qualitative data we collect from the MPI interviews, we also used two questionnaires to capture quantitative data. The first questionnaire asked participants to rate their tactile perceptions of each fabric on 26 sets of bipolar descriptor pairs on a 7-point bipolar rating scale (i.e., Technical = 1 vs Human = 7) (Table 2). These descriptors represent both the most common components

Table 2: Summary of 26 questionnaire items (i.e. adjectives) used in the user study to assess user's tactile perceptions. Each selected item is based on prior literature; references provided.

Adjectives	References
Rough/smooth	[9, 28, 49]
Uneven/flat	[28]
Itchy/not itchy	[28]
Strange/usual	[28]
Significant/Insignificant	[28]
Sharp/dull	[28]
Natural/artificial	[28, 49]
Delicate/bold	[28, 49]
Stylish/tacky	[49]
Predictable/Unpredictable	[49]
Slippery/sticky	[49]
Wet/dry	[9, 28]
Clear/vague	[49]
Modern/classic	[49]
Interesting/uninteresting	[28]
Good/bad	[28]
Confusing/clearly structured	[49]
Friendly/unfriendly	[28]
Fluffy/not fluffy	[49]
Soft/hard	[49]
Elastic/not elastic	[49]
Heavy/light	[9]
Coarse/silky	[9]
Enjoyable/not-enjoyable	[9]
Pleasant/unpleasant	[9]
Relaxing/tense	[9, 49]

of tactile descriptions [41] and the most relevant fabrics touch experience descriptors [49]. This selection of descriptors was further supported by a review of prior works assessing tactile perceptions and emotional responses to surface textures (see an overview in Table 1). The second questionnaire consisted of the Self-Assessment Manikin scale (SAM) [6] which was used to investigate participants' affective responses to each fabric. Participants were asked to rate each fabric on three main dimensions: valence (experienced emotion), arousal (intensity of the emotion), and dominance (control over the felt emotion) using a Visual Analogue Scale (a continuous rating scale 1-9). SAM has been widely used within HCI research, especially to assess emotional responses to tactile stimuli (e.g. [31]).

3.4 Participants

A total of 27 participants (14 female, 13 male, aged 18 – 45 years, Mean = 28.5, SD = 33.4) volunteered to take part in this study. None of the participants reported any impairments related to their sense of touch (e.g. neuropathy, vascular problems) that would impact their perception of the fabric samples. 24 participants were right handed, two were left handed, and only one participant reported to use both hands equally in everyday activities. We also asked about their first language (mother tongue) which is relevant for the MPI technique [36]. A total of 51.8% of the participants declared English as their first language and 96.3% stated they had lived in the English-speaking country (study country anonymised) for at least the last six months. Among the 27 participants, 6 participants reported that they have hobbies related to textiles/fashion design (e.g. sewing, knitting, crochet).

3.5 Analysis Procedure

3.5.1 *Interview analysis.*

The audio and video recordings of all sessions were transcribed and analyzed in accordance with their diachronic and synchronic structure [27, 51]. All transcripts were initially reviewed independently by the main coder and the analysis was carried out using NVivo, a qualitative data analysis software (Version 1.6.2, March 2022).

A total of three coders took part in the analysis process, including one main coder with a background in user experience research and two MPI experts with extensive experience in user experience research to review and validate the methodology and process. Analyzing the collected data and validating the results was an iterative and reflective process. All coders participated in the process of reviewing the emerging coding scheme and agreeing on changes.

The first steps of coding were done deductively, that is, each fabric was described separately with phrases and sentences in accordance with the participant's expressions. These phrases (e.g., "like a wintery fabric") and sentences (e.g., "it is nice and pleasant") formed the basis of the initial groupings of codes. We synthesized repeated codes and similar verbalisations into words/phrases to give each group a unique code. For example, during the interview, P020 describes their feelings towards *F5*-Velvet as follows: *"I am thinking of like, I don't know why, like a velvet waistcoat..."*. In this case, we group such expressions into *"association to object"*. In the subsequent analysis step, these groups were assigned to the diachronic and/or synchronic dimensions of the experience based on the temporal evolution and the context of the verbalisation. Each coder reviewed the coding results independently and discussed the temporal evolution of the verbalisations and their contexts. The final categories, as well as synchronic and diachronic structure, were then reviewed and discussed by all three coders to ensure that the results accurately reflect the synchronic and diachronic structures of fabric tactile experiences. This was an iterative process over three months.

3.5.2 *Questionnaire analysis.*

The findings of the qualitative analysis were then corroborated with the results of the tactile and affective experience questionnaires (as mentioned in 3.3.2). For the affective experiences questionnaire (SAM), outliers on the valance, arousal, and dominance scales across all nine fabrics were removed if they fell outside of the median +/- 2.5 x the Median Absolute Deviation (MAD). To investigate whether the fabrics differed in terms of affective experiences, Linear Mixed-Effects models (LME) were applied (similar in interpretation to repeated-measures ANOVAs). For the tactile experience questionnaire, the ratings of each of the 26 adjectives were averaged across the nine fabrics and compared against a null value of 0 (representing no significant opinions) using non-parametric one-sample t-tests. To control for inflated Type 1 error rate and to identify only the primary tactile dimensions, False Discovery Rate correction for multiple comparisons was applied [4] and only significant results returning a large effect size were considered. These affective experiences and identified tactile dimensions were then integrated into the qualitative findings. The statistical analyses were conducted using R Studio [50] using several data visualization [54] and statistical packages [13, 26].

4 RESULTS

A total of 2945 participant expressions were extracted from the interview transcripts of 27 participants (3 fabric-specific interviews per participants) and categorised into six overarching diachronic categories and 23 synchronic subcategories. The categories were

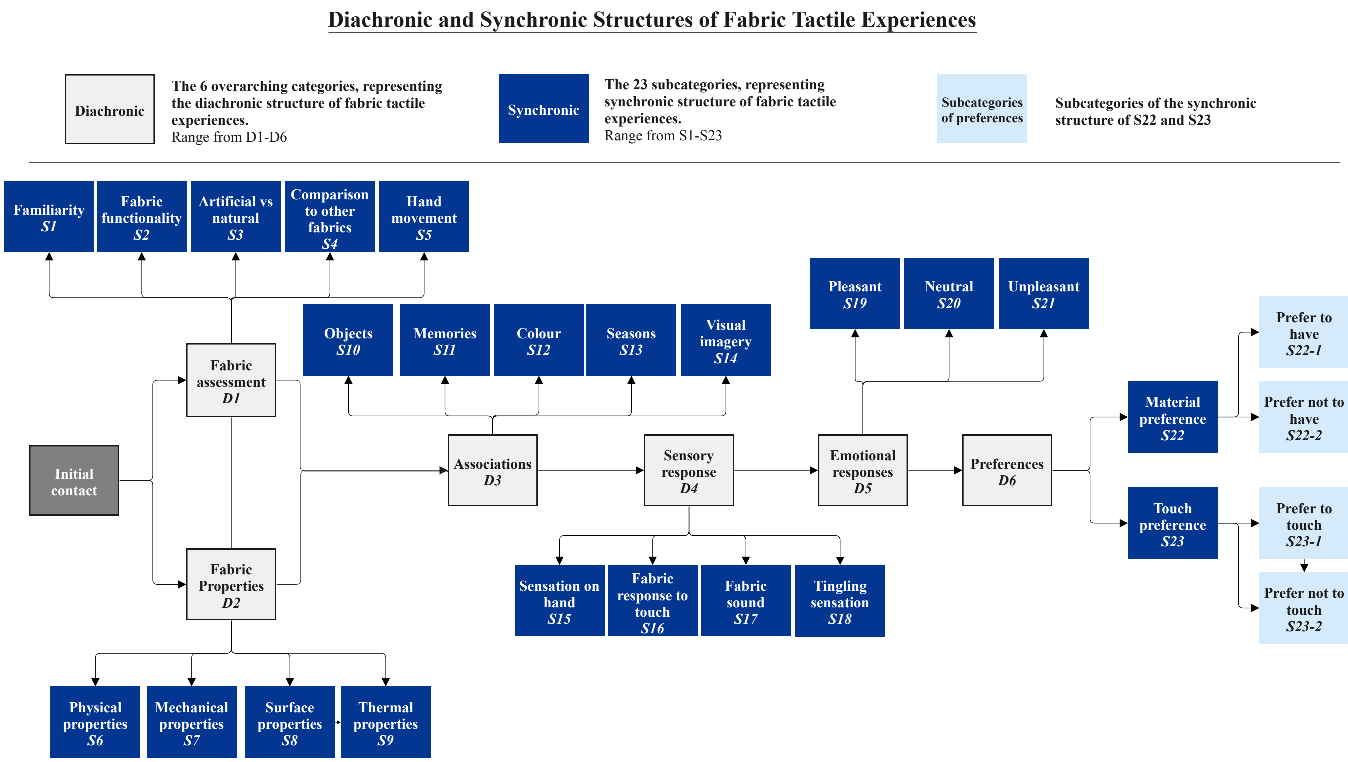


Figure 4: Diachronic and synchronic structure of fabric tactile experiences, starting from the initial contact with the fabric and unfolding over time. We identified 6 overarching diachronic categories (D1-D6), and 23 subcategories (S1-S23) with additional branches in S22 and S23 for material and touch preferences.

cross-validated with prior literature and results from the questionnaire data. For simplicity, we use D1-D6 to refer to the 6 overarching diachronic categories: D1-Fabric assessment, D2-Fabric properties, D3-Association, D4-Sensory responses, D5-Emotional re D6-Preferences. We use S1-S23 to refer to the synchronic subcategories. Figure 4 shows an overview of the overall diachronic and synchronic structure of fabric tactile experiences.

Overall, participants expressed *D1-Fabric assessment* (34% of total references) and *D2-Fabric properties* (24% of total references) more frequently than other expressions. By contrast, participants tended to express less about *D3-Associations* (15% of total references) and *D4-Sensory responses* (13% of total references). When compared to the *D3-Associations*, the *D5-Emotional responses* (11% of total references) that reflect pleasant or unpleasant feelings towards the fabric tactile experiences were less frequent. There was a much lower level of expressions for *D6-Preferences* than for the other categories, which only accounted for 3% of abstracted expressions. An overview of the overall proportion of the participants' expressions is shown in Figure 5:(I).

In the next section, we describe the details of the diachronic and synchronic structures of the fabric tactile experiences as they unfold over time. The abstracted expressions of fabric tactile experiences were incorporated into the diachronic (*D1-D6*) and synchronic (*S1-S23*) structure of the users' fabric tactile experiences (as shown in Figure 4).

4.1 Diachronic Structure of Fabric Tactile Experiences

During the interview, participants generally began by expressing their tactile perceptions of the fabrics. There was a great tendency (34% of total references) for participants to describe either how their hand assessed the fabrics or the properties of the fabrics they explored. As an example, a typical description was, "I put my hand in and I start to touch it the first time. I feel it's very soft and smooth..." (P001, F2-Flannel). This phrase includes two important pieces of information: "I put my hand in" describes how participants moved their hand, and "I felt it was very soft and smooth" describes how the F2-Flannel's surface felt. It was therefore determined that these kinds of expressions could be classified into two categories: 1) *D1*-in which participants express their assessment of the fabric, and 2) *D2*-in which participants describe the fabric's properties.

Moreover, when participants were prompted to describe the feeling on their hand in more detail, they tended to relate to their own past experiences when describing the sensation. These types of expressions often indicate an *D3-Association* between their past experiences and the present. Examples of such responses can be found in participant P006's comments about how "...this one triggered a kind of a, I guess a memory or a feeling or an idea. It makes me think of you know, like dusters for dusting". This type of expression illustrates how participants relate tactile experiences to objects they have previously encountered.

Further, as participants were asked to describe in more detail their feelings or thoughts, they tended to link to more *D4-Sensory responses* (e.g. sounds) before expressing their *D5-Emotional responses* (e.g. pleasant). In this case, typical expressions of such were, for example, one participant mentioned "Okay, as I try to pay attention to the sound it creates. It is a very loud song, but it is also not disturbing" (P001,F3) In this case, participants expressed the sensation of the sound before expressing the emotional response of "not disturbing", as a consequence of which participants expressed that the sound was not disturbing.

Following the expression of emotional responses, only 3% of expressions were specified related to preference for the fabric (*D6-Preferences*). "I think it's my personal preference. I don't like hard fabrics"(P019) and "I am thinking like, oh, this won't work for me if it's see-through so I am thinking like if I'm in a shop and I find this fabric I'm not be torn towards buying such a fabric"(*P007*) are examples of people expressing their preferences towards fabrics. On the other hand, people tended to express more tactile preferences, such as, "...so it invite me to explore more, you know, the aspect that it was something new"(*P018*), or "it makes me think, yeah I like what I'm doing. I would like to feel it more"(*P001*). In the experiment, participants were not allowed to have any visual information when expressing their preferences, which may explain the differences in preferences expressed.

As the analysis process of the interview progressed, an underlying temporal structure (diachronic structure) emerged and became more visible. In response to questions regarding their tactile experiences with fabrics, participants often began by expressing a combination of *D1-Fabric assessment* and *D2-Fabric properties* before expressing *D3-Associations*. Following these expressions, participants are more likely to express their *D4-Sensory responses* before their *D5-Emotional responses*. Some of them ended by expressing their *D6-Preferences* towards either *S22-Material preferences* or *S23-touch preferences*.

4.2 Synchronic Structure of Fabric Tactile Experiences

We describe the details of our synchronic structure (*S1-S23*) regarding to each of the six diachronic structure (*D1-D6*) and their correlation to each fabric samples (*F1-F9*).

D1 Fabric assessment

Initial references made by participants throughout the interviews focused on the way they assessed the fabric (*D1*). A typical description by participants of fabric assessment of the fabric tactile experiences varies from *S1-familiarity*, *S2-fabric functionality*, *S3-artificial vs natural feeling*, *S4-comparison to other fabric*, and *S5-hand movement*, each of them can be distinguished based on the expressions of participants. In general, participants express more of *S5* (450 references in total), compare to the expression of *S3* of the fabric (55 references). The general trend of the distribution of expressions for each subcategory is shown in Figure 5: II).

When the interviewer asked the participant to explain what happens first, one typical example of expressions of *S5* could be found during the interview for the F3, following participant P016's response: "I start chasing my fingers around it and then I pick it up and started...moving my hand gently along it rather than rubbing it" (P016, F3). While discussing the fabric, the participant has been moving his or her hand up and down in the air to demonstrate how they explore the fabric by hand. While a large number of expressions are emphasized on the *S5*, there is a possibility that this is a result of the questions the researcher was asked.

There is, however, a clear tendency among participants to compare the fabric they explored with other fabrics or materials they have encountered before (*S4*). As an example, during the interview process, P014 expressed: "it's not the same as nylon... Nylon is generally very smooth, and this is not smooth" (P014, F8). In this case, the participant compared the fabric to nylon, a synthetic material, to indicate its smoothness. It is particularly evident in the case of F6-Voile, as most participants tend to compare the tactile properties of this fabric with those of other materials such as silk, polyester, etc.

Furthermore, there are 136 expressions in which participants attempted to guess the fabric's functionality. As an example, one participant stated: "...that is not something that is not really for cloth and not even for objects that you have. It looks like something that you use in the lab or contest" (P001, F3) during the interview with F3-Buckram. It is evident that participants expressed a greater degree of *S2* in relation to F2-Buckram, F3-Flannel, and F4-Organza. There is a possibility that this trend can be explained by the fact that these fabric samples exhibit more surface tactile perceptions, such as roughness, smoothness, and softness.

There were fewer expressions abstracted from the transcripts for Familiarity (*S1*) and Artificial vs Natural (*S3*) categories, which may have been due to a lack of visual information. For the fabric sample F2-buckram, according to P013: " I think I am just at that point, it is me thinking, Oh, I know, because I couldn't see. So it was me trying to convey something I had visual information about it is. I think I know what it might be....So this is a table mat, which is I think, is probably plastic or something..." (P013,F2). In this case, the participant expresses that there is a familiar feel (*S1*) with this fabric despite lacking visual information. It is assumed by the participant that this is a table mat made from "plastic" which is an artificial material (*S3*).

D2 Fabric properties

Parallel to the expressions for the assessment are the expressions for the fabric properties. To analyze the expressions for fabric properties, we first grouped similar expressions together. As a result, 11 groups of expressions were summarized. A comparison was made between the "textile hand" [3, 11, 39] and surface tactile perceptions [32, 41, 55] in order to determine the names of each group. We have identified 13 groups of expressions, including edges, flexibility, thickness, thickness, weight, fluffiness, regularity, roughness, softness, wetness, conductivity and temperature.

A review of the fabric properties of "textile hand" was conducted following the classification of the expressions, whereby the fabric properties were classified based on objective measurements of fabrics' physical properties (such as thickness and mass per unit area), mechanical properties (extensibility, bending properties, shear), surface properties (compression, friction, surface irregularities), and thermal properties (temperature, conductivity) [3, 11, 39]. As a result, the groups of expressions were categorised into subcategories under the fabric properties as: *S6-Physical properties*, *S7-Mechanical properties*, *S8-Surface properties*, and *S9-Thermal properties*.

A total of 690 expressions were abstracted for *D2-Fabric properties* among all participants. Clearly, participants are more likely to express their opinions regarding Surface Properties (*S8*, as shown in Figure 5, III). In particular, greater expressions can be observed in the surface properties of F3-Buckram, F4-Organza, and F5-Velvet. Nevertheless, these groups of expressions which represent the participants' tactile perception of the surface of the fabric exhibit five distinct groups, namely *fluffiness, regularity, roughness, softness*, and *wetness*.

There is also a tendency among participants to focus only on the *edge* and the *flexibility* of the fabric when expressing *S7* (see 5, III). In particular, this can be seen in the expressions of the fabric samples F3-Buckram and F4-Organza. This can be illustrated by one participant P018's comment for F4-Organza as follows: "It very easily bends...then the edges feel a bit rough and coarse and can almost...feel almost like it was very, very fine" (P018, F4)

S6-Physical properties were not expressed as much as *S8-Surface properties* and *S9-Thermal properties* by participants, however fabric samples F1-Heavy Drill, F4-Organza, and F8-Muslin demonstrate greater expressions of *S6*. In the interview, participants emphasized the *thickness* and *weight* of the fabric when discussing its physical properties. For instance, when the participants were asked to express their feelings towards the fabric more in detail, participant P016 during the interview with F1-Heavy Drill mentions "It feels quite thick...it seems substantial and heavy. I can feel some weight to it" (P016, F1)

While there is a trend of participants expressing less information about the *S9-Thermal properties* of the fabric, in the case of F2-Flannel and F5-Velvet, participants are more likely to mention how fabric properties relate to *temperature*. It is likely that this tendency arises from the softness and fluffiness of these fabrics.

D3 Associations

It is often the case that participants describe their association with other *S10-Objects* after they describe *D1* or *D2* (as shown in Figure 5, IV). The tactile experience with sample fabric was expressed by participants in a number of ways, many relating the tactile experience to an object or the material of an object that they have encountered previously. A typical example would be: "...but the first thing I connected with, this to, was the scarf. I think more than anything else" (P001, F8). While there are fewer expressions related to *S11-Memories* in this series, the expressions of memory association are often highly associated with *D5-Emotional responses* in some circumstances. For example, one particular expression relating to memories of F2-Flannel is by P011: "It is a cotton fabric and I feel like...I miss my mom. Okay. It makes me feel emotional" (P011, F2)

In addition, certain associations with an object are related with seasonal associations (*S13-Season*), as participant P004 expressed in an interview about fabric sample F2-Flannel: "for example, I think about a scarf, and in the winter, maybe you like want you have it. So maybe because scarf is something that keeps you warm in the winter during the winter" (P004, F2).

Intriguingly, participants were able to associate certain colours (*S12-Colours*) with their tactile experiences with the fabric samples. A typical association to colour can be seen in P009's response to fabric sample F9-Twill: "It's kind of like light blue-ish. It's a bit lighter than the other, but not as light as the other...like in between" (P009, F9)

The participants also mentioned that they attempted to visualize the fabric in their minds(*S14-Visual imagery*). Eight participants mentioned that they associated the tactile experience with certain visual images. Participant P007 expressed these expressions towards F6-Voile in the following manner: "I think it comes to my mind like walking during summer and then like I could feel the air coming in and not feeling very hot if I'm wearing such a fabric" (P007, F6).

D4 Sensory responses

In response to the question regarding how the fabric sample feels on their hand, participants tend to respond based on the *D4-Sensory responses* they experience. There is a clear trend in expressing the position of the sensation on hand (*S15-Sensation on hand*) (as shown in Figure 5, V). The most commonly mentioned position of the sensation would be on the palm and the fingertips.

A further interesting finding in the participants' expressions was that when the participants were asked to describe in detail the fabric properties that they feel, they tend to describe the interaction as if the fabric is actively interacting with their hands (*S16-Fabric response to touch*). In the interview for the fabric F5-velvet, for example, participant P010 stated "At some point your finger will jump down because all the hairs will align and fall together as you move your finger over" (P010, F5). In this case, the participant described the fabric as it is "actively" interacting with his/her hand.

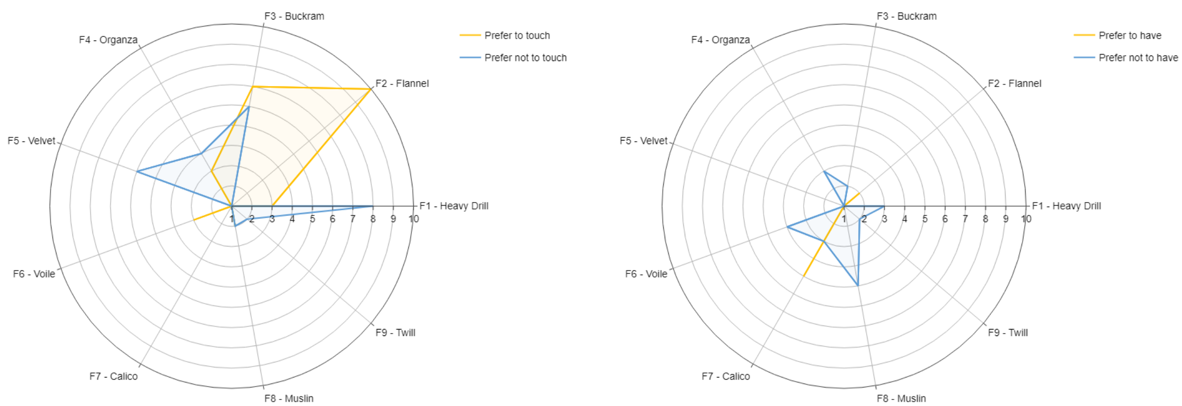
As a matter of interest, among all the interviews with 9 fabric samples, five samples (F1-Heavy Drill, F3-Buckram, F4-Organza, F6-Voile, F8-Muslin, F9-Twill) were noted to have produced sounds (*S17-Fabric sound*) when participants examined the fabric with their hands. According to participant P009 during the interview for the fabric F1-Heavy Drill: "The sound was also something that caught my attention because it was like really loud in a way, and what I was doing with my nails was like scratching the patterns... it was a bit more like high pitch nails and then a low pitch between the corner and fabric" (P009, F1).

In addition to the sensory responses discussed above, the participant mentioned *S18-Tingling sensations* which we feel are distinct from others, as indicated by participant P003's statement: "...somehow the nervous system gets triggered and it gives out some sort of tinkling that is sent to the brain" (P003, F6). In spite of this, these expressions did not appear to be central to these touch experiences, as only three fabric samples were mentioned regarding the sensation of tingling, namely F1-Heavy Drill, F6-Voile, and F9-Twill.

D5 Emotional responses

It is evident from the participants' *D5-Emotional responses* (e.g., pleasant/unpleasant), that people express more *S19-Pleasant feelings* toward fabric samples than neutral (*S20*) or unpleasant emotions (*S21*) (as shown in Figure 5: VI). Particularly, F2-Flannel and F4-Velvet tend to evoke pleasant emotions due to their softness and fluffiness [35]. The expression *S19* can be found in P011: "...very happy after touching it. And very emotional too. I don't know what kind of emotion it is, but yeah, I am happy" (P011. F2). As opposed to this, when participants express unpleasantness, a typical expression

Figure 5: (I) An overview of the overall proportion of the participants' expressions; (II) Distribution of abstracted expressions of *D1-fabric assessment* for each fabric sample; (III) Distribution of abstracted expressions of *D2-Fabric properties* for each fabric sample; (IV) Distribution of abstracted expressions of *D3-Fabric associations* for each fabric sample; (V) Distribution of abstracted expressions of *D4-Fabric sensory responses* for each fabric sample; (VI) Distribution of abstracted expressions of *D5-Emotional responses* for each fabric sample.



(a) (I) Touch Preferences

(b) (II) Material Preferences

Figure 6: (I) Touch preferences expressions for 9 fabrics; (II) Material preferences expressions for 9 fabrics.

is by P005: "So I guess I am disapproving of it. I am unimpressed by it" (P005, F4)

D6 Preferences
Despite the above emotional responses, only 93 references were extracted concerning fabric preferences. There was potentially a greater likelihood of expressing *S23-Touch preferences* (57 references) due to the study's focus on tactile experiences (as shown in Figure 6). In accordance with the results shown in Figure 6, **(I)**, F1-Heavy Drill is the least preferred fabric out of the 9 samples, whereas F2-Flannel is the most preferred fabric to touch. An example of such touch preferences could be found with P008 expression with F2-Flannel: "I am willing to touch it longer and until you tell me to stop. I didn't realize that time had already passed" (P008, F2). In contrast, for *S22-Material preferences*, participants expressed more desire to have F7-Calico rather than F8-Muslin (as shown in Figure 6, **(II)**). For instance, P007 expressed their material preferences as: "This is something that I would wear" (P007, F7).

4.3 Tactile Perception and Emotional Responses Questionnaires Analysis

To cross-validate the above qualitative findings, we analysed the participants' tactile and affective perceptions on the quantitative questionnaires.

4.3.1 *Tactile perception questionnaires*.

Participants were asked to fill out a questionnaire regarding their tactile experiences in relation to the 26 adjectives, with ratings ranging from -3 to 3 (e.g., -3 = Technical, 3 = Human, see Supplementary Material). To identify only the most primary fabric surface tactile perception dimensions expressed by participants [32, 41, 55], we considered only results that survived correction for multiple comparisons and returned a large effect size (as shown in Table 3). According to participants, these primary fabric surface tactile perceptions are *Wet/Dry*, *Uninteresting/Interesting*, *Confusing/Clear Structured*, *Not fluffy/Fluffy*, and *Not elastic/Elastic*. These findings support the qualitative results, since participants expressed *Not elastic/Elastic* under the *flexibility* group within the *S7-Mechanical properties* of the fabric. In addition, they expressed *Not fluffy/fluffy* as well as *Wet/Dry* within the *S8-Surface properties*. Moreover, the *Confusing/Clear Structured* could be found in the participants' expression of *S1-Familiarity* when they express how they assess the fabric (*D1-Fabric assessment*). Only one pair of adjectives did not appear in the interview, *Interesting/Uninteresting*. This could be due to the fact that this question was not specifically asked or perhaps participants were referring to the experimental situation.

Table 3: Results of t-tests comparing adjective ratings against a null value of 0. Only tests that survived False Discovery Rate (FDR) correction for multiple comparison and produced a large effect size were considered. The following adjectives were the primary tactile experiences adjectives used by participants.

Adjectives	p_{FDR}	Rank-Biserial Correlation	Effect Size
Wet/Dry	0.001	1	Large
Uninteresting/Interesting	0.001	0.85	Large
Confusing/Clearly Structured	0.001	0.86	Large
Not Fluffy/Fluffy	< .001	-0.93	Large
Not Elastic/Elastic	< .001	-0.94	Large

Note: FDR is False Discovery Rate corrected; Effect Size is interpreting the size of the correlation.

4.3.2 *Emotional responses using (SAM)*.

According to our interview analysis, tactile experiences possess a high level of valence, and they are highly associated with pleasant/unpleasant experiences. We cross-validate our result by examining the relationship between fabric tactile experiences and valence, arousal, and dominance.

Valence A Linear Mixed-Effects (LME) model was calculated to predict valence ratings from the Random-Effect of participant and the Fixed-Effect ('main effect') of fabric. This model was a significantly better fit to the data than the null model ($X(8) = 58.4$, $p < .001$, $R^2 = 0.21$). Valence ratings significantly differed between fabrics ($F(8, 201) = 8.1$, $p < .001$) which post-hoc t-tests revealed was due to valence ratings being higher for Velvet relative to all other fabrics (all $p_{Holm} < .001$) except for F2-Flannel ($p_{Holm} = .726$) and ratings being higher for Flannel relative to F3-Buckram and F4-Organza (both $p_{Holm} < .001$), but not the remaining fabrics (all $p_{Holm} > .062$). All other comparisons were non-significant (as shown in Figure 7, I).

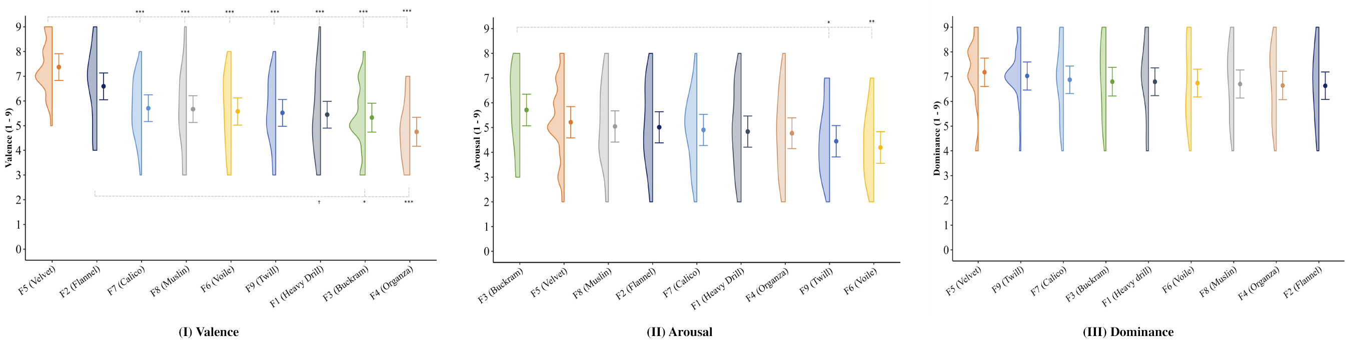


Figure 7: (I) Valence of F1 to F9; (II) Arousal of F1 to F9; (III) Dominance of F1 to F9. The left hand side of each plot represent the distribution of responses and the right hand side represents the estimated parameter (e.g., mean) of the Liner Mixed-Effects models and respective 95% Confidence Intervals. Note: † = *p* < .1, * = *p* < .05, ** = *p* < .01, * = *p* < .001.**

These results are consistent with qualitative data which suggested a high proportion of references regarding pleasantness for F2-Flannel and F5-Velvet as illustrated in Figure 5, VI).

Arousal A further LME model predicting Arousal ratings was also a significantly better fit to the data than the null model (X(8) = 23.229, p = .003, R^2 = 0.06)). Arousal ratings significantly differed between fabrics (F(8, 189) = 3.0, p = .003) due to higher arousal ratings for Buckram relative to both Twill (p_{Holm} = .017) and Voile (p_{Holm} = .002), but no other comparison returned significant (all p_{Holm} > .270), as shown in Figure 7, II. This is mostly consistent with the analysis of the interview, as participants tends to find F3-Buckram is "surprising", as P016 expressed during the interview: "Oh I am a bit surprised when I touch it because like I am expecting just normal textiles as a normal soft fabric".

Dominance The final LME predicting dominance ratings was not a significantly better fit to the data than the null model (X(8) = 7.2, p = .518) and dominance ratings did not significantly differ between fabrics (F(8, 183) = 0.875, p = .528, R^2 = 0.008) (as shown in Figure 7, III). This result is consistent with the results of the interview analysis, which indicates that there are no abstracted expressions of dominance.

Overall, these quantitative findings suggest that fabrics varied in their valence ratings, varied to a lesser extent in terms of arousal, and no differences in dominance were found. These findings support our qualitative results which indicated a similar pattern (as discussed above).

5 NOVEL INSIGHTS INTO FABRIC TOUCH EXPERIENCES

In this paper we investigated fabric tactile experiences by combining qualitative and quantitative methods. Based on the richness of analysing the diachronic and synchronic structure of participants' experiences with nine fabric samples, we constructed an experiential mapping over time which shows the richness of the experiences as they unfold.

This study found that users' tactile experiences go beyond objective measurements of the "textile hand" [3, 11, 39] and surface tactile perception dimensions [32, 41, 55]. According to the prior work on the *"textile hand"*, the handling of textiles concerns the objective measurements of the fabric properties, namely physical, mechanical, surface, and thermal properties (as discussed in 2.1). In our study, similar expressions related to fabric properties were observed, however, those fabric properties including physical, mechanical, surface, and thermal properties only represented 23% of the overall users' expressions of their fabric tactile experiences. Moreover, surface tactile perception studies indicate that roughness, compression, warmth, silkiness, and material characteristics are the most commonly cited dimensions of surface tactile perception of fabric [32] (as shown in 2.2). However, our findings from the tactile questionnaire suggest that fabric surface tactile experiences are highly correlated with *flexibility, fluffiness, regularity, and wetness*.

In spite of the fact that our interview analysis suggested a similar pattern as the tactile questionnaire result, the total number of references expressing these experiences only accounted for a small proportion (24%) of the fabric property responses during the interview (see Figure 5:(I)). Therefore, this study suggests that the tactile responses of users to fabrics are not solely determined by fabric handling properties or surface tactile perceptions, but are a rich experience involving *fabric assessment*, *fabric properties*, and *sensory responses*. Furthermore, our results indicate that fabric tactile experiences are highly affective in nature. Prior studies on affective responses often focus on the emotional responses (e.g. valence, arousal, dominance) [9, 48]. In our analysis, fabric tactile experiences were strongly associated with valence, whereas arousal and dominance were not associated. Based on our interview analysis, we discovered that the users' affective responses encompass more than emotional responses, including *associations*, *preferences*, as well as *emotional responses*.

5.1 FabTouch Tool Design

The term "tool" refers to a kit that can be used by users or experts to carry out tasks assigned to them [53]. In this paper, based on the novel insights into fabric tactile and affective experiences we created the FabTouch tool. FabTouch is a physical representation of user-derived tactile and affective fabric experiences that has the potential to assist both users and professionals in carrying out fabric or fashion related design tasks. The tool unfolds like an accordion book with each part following the diachronic and synchronic structure of the identified fabric touch experiences (see Figure 8).

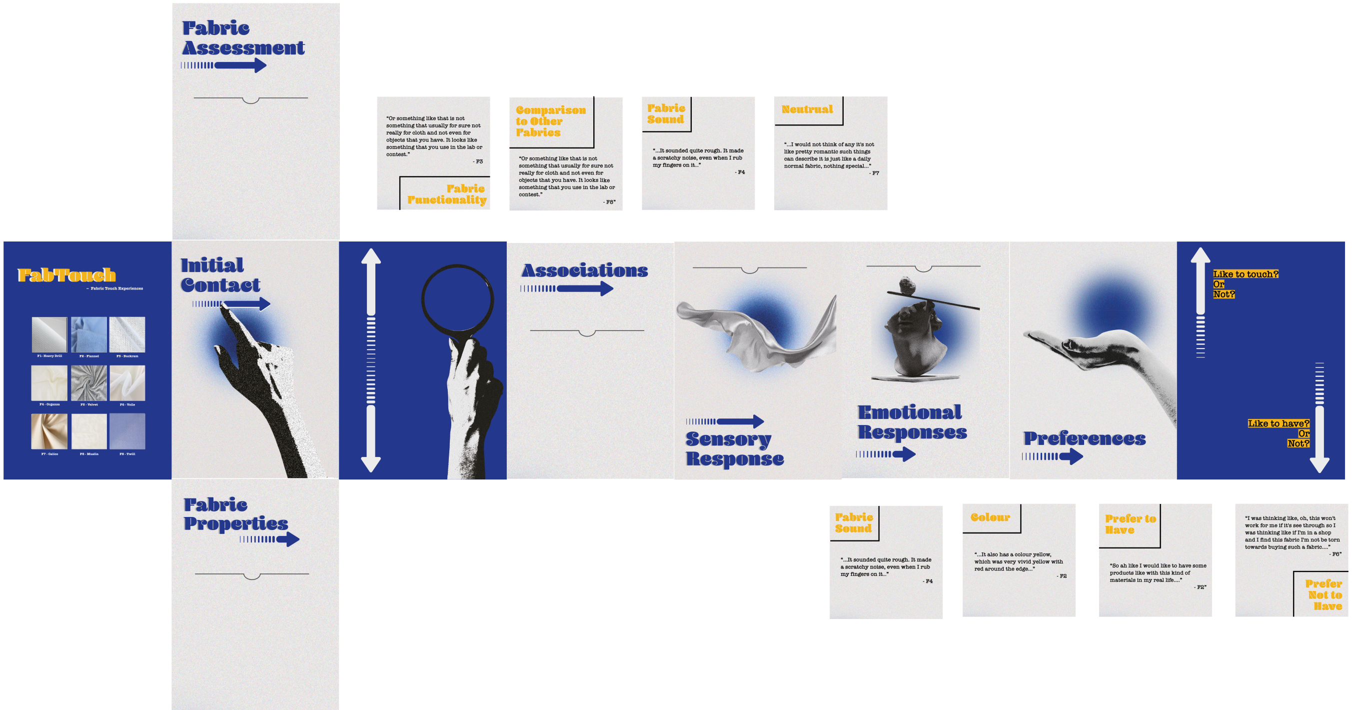


Figure 8: The unfolded FabTouch tool with example cards for the fabric touch experiences, including exemplifying expressions from participants, linked back to the cotton fabric (F1-F9).

As the FabTouch tool unfolds, tactile experiences are revealed and a stepwise engagement with the included content is enabled (6 overarching categories and 23 subcategories). The users' experiences are presented in detail by creating cards that sit in the accordion book pockets (each representing one of the six diachronic/temporal categories). The pocket cards contain the synchronic categories descriptions (specific details on the configuration of the experience) and example expressions (i.e. verbatim quotes) from our participants, linked to example fabric samples in that category. The complete set of cards can be found in the Supplementary Materials.

FabTouch is only one part of a potential future toolkit we envision to explore the design space around fabric touch experiences. Establishing a detailed understanding of users' tactile and affective experiences with physical fabrics is a crucial first step when moving from physical to digital fabric touch design opportunities.

5.2 Engaging Designers with FabTouch

To gather initial feedback and reactions, we presented the FabTouch tool to four designers from different backgrounds and perspectives: two designers were fashion designers, one tactile interaction designer, and one fashion accessory designer from the industry. Below we describe our semi-structured interview approach and provide a summary of the designers' feedback, highlighting two applications opportunities.

5.2.1 *Interview approach.*

We interviewed four designers to gather initial impressions on the FabTouch tool. All interviews were conducted in an relaxed environment of the interviewees' preference, and lasted approximately 1.5 hours each. All interviews were conducted in a semi-structured manner [16, 21], where we began by introducing our FabTouch tool. We first explained the six diachronic/temporal categories to the designers, followed by presenting the pocket cards in the FabTouch tool representing the synchronic/experiential categories, which contain examples of expressions for each category. Then we continued with a set of guiding questions including: *"What do you think of the FabTouch tool?" "Would you use this tool in your design/working process? If yes, what would you do with it? If no, what is the reason for not using it?" "In your opinion, how could the FabTouch tool help other designers or users/consumers?"*. This set of guiding questions was further extended based on the designers responses, allowing an open conversation between the researcher and designer. Below we summarise some of the key insights gained from this early engagement with designers.

5.2.2 *Initial feedback and design opportunities.*

The discussions revealed that designers from different professions tended to have different perspectives on how fabric experiences unfold over time. For example, during the interview, a fashion designer mentioned that the primary difference between them as a fashion designer and textile designers is the sensory modality each of them focuses on in the design process. The designer explained that fashion designers tend to focus more on aesthetics than on touch experiences when designing their garments; while textile designers are more concerned with the texture and feel of the textile they work with. In consequence, these differences led to different interpretations of fabric experiences, both with regards to the diachronic and synchronic categories being considered as part of the design and ideation process. In fact, FabTouch was perceived as a possible tool to bridge different perspectives and provide a common reference point for discussion, not only between designers, but also when engaging with clients and possible customers. FabTouch can make experienced professionals more aware of the user-derived experimental mapping of fabrics [37].

FabTouch was also considered a valuable educational tool. For example, one fashion designer, expressed excitement about the opportunity to use FabTouch to teach fashion and textile students about the tactile experiences of consumers, fostering a unique new perspective students can learn as part of the design process. In the same vein, the fashion accessory designer remarked that FabTouch could be a useful tool to educate and remind designers about the tactile and affective experiences users have with fabrics. The designer said that this tool could be very useful in practice, to enrich and challenge existing opinions throughout the design process. Moreover, the fashion accessory designer suggested that FabTouch could provide designers with a tool to visualise their own temporal fabric experiences. For example, when designers are instructed to design a new garment, FabTouch can help them in creating their own version of fabric tactile experiences and how they unfold over time (using a blank version of FabTouch). The outcome can then feed into the conversation with colleagues to uncover commonalities and differences, as well as to cross-check their assumptions with the user-derived experimental mapping described in this paper. During meetings and design processes, designers are then enabled to determine whether they share their opinions regarding the tactile and affective experiences with others or not, opening up space for questioning and reflection.

Furthermore, by comparing their version of fabric experiences with the users' fabric experiences from FabTouch, designers can gain a deeper understanding of the different perspectives that fabric experiences offer. These comparisons have great potential to inspire designers to develop garments that engage users on a tactile and affective level and initiate a dialogue regarding the design of tactile and affective fabric experiences. While our exploration was focused only on a small selection of fabric samples, designers recognised the potential to expand on the types of fabrics in the future, and thus its scope across various fashion domains (e.g. from garments to accessory design).

6 DISCUSSION AND FUTURE WORK

In this paper, we presented a tool to enable communication and design of tactile and affective fabric experiences. Based on those initial conversations with designers 5.2, the FabTouch tool can facilitate a dialogue amongst designers, be explored as an educational/reflective tool both in academia and practice. Moreover, while FabTouch could provide designers with visualisation and comparison of fabric experiences, it could also inspire more engaging digital fabric design. In a recent study done by Price et al. [42], they argued that we are reaching a critical point for digital communication where we are moving from "ways of seeing" to "ways of feeling" in the digital space. This was also highlighted by the tactile interaction designer we interviewed. They emphasised the importance of engaging different sensory modalities as well as affective responses when digitally designing fabric products.

Furthermore, as discussed in 2.3, digitally communicating fabric products should consider physical properties and perceptual effects to communicate textile experiences in a more immersive way to consumers [2]. FabTouch can help designers to better understand users' fabric tactile experiences and, more importantly, their associated affective responses when designing digital fabric experiences. Moreover, FabTouch can be a tool to assist in bridging the physical with the digital design space around fabric tactile and affective experiences.

While our research and the derived FabTouch tool provide valuable insights into fabric touch experiences and opportunities for designers, we also like to acknowledge the limitations of our work. Our study focused on a limited number of fabric samples. Despite the fact that cotton samples are one of the most commonly used natural fabrics in the world [19], future studies are needed to extend the range of fabric types and textures in order to enrich the fabric experience mapping. Moreover, our choice of a mixed method approach, combining MPI interviews with questionnaires, requires a resource-intense data collection and analysis process which may not be easily applied in practice, where time and resources are limited [52]. However, we hope the detailed description of our methodology allows a more efficient use to extend the sample size of participants to validate and consolidate the mapping of the fabric experiences. This mapping could also be further extended with objective measurements for each fabric (for example Fabric Touch Tester measurements (FTT) [23]) to account for the mechanical properties of each fabric. Finally, our engagement with designers was only a first step as part of this work; more in-depth studies with designers using the FabTouch tool are needed in order to expand on its initial identified values/benefits, as well as to apply it to specific design challenges and processes.

7 CONCLUSION

This paper provides a comprehensive analysis of user's fabric tactile experiences concerning tactile and affective responses. We present the results on the synchronic and diachronic structure of those experiences. Through qualitative and quantitative methods, we demonstrated that tactile experiences of fabrics involve a variety of perceptual experiences related to tactile perception, including *fabric assessment*, *fabric properties*, and *sensory responses*. Also, we observed a wide range of affective responses to fabric tactile experiences, ranging from *emotional responses* to *associations* to *preferences*. The results of our study indicate that fabric experiences are not only tactile, but also influenced by sound and visual imagery. For the first time, we provided a comprehensive review of temporal users' fabric tactile experiences, which could be used in designing fabric tactile experiences through an experiential and multisensory lens. From initial engagement and discussion with fashion, textile and tactile interaction designers, we believe FabTouch opens up a space for a rich experience-based reflection for designers on their own understanding of fabric-touch experiences, facilitates a dialogue amongst designers from different expertise, and may become an educational tool for design students. Above all, FabTouch can open up a dialogue with consumers and clients in a physical and digital space; a research direction for future work. Further research can now investigate how this mapping of temporal fabric experiences can be related to objective textile material measurements (i.e., fabric properties) in order to develop a structure that reflects the relationship between the textile hand and the affective responses.

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