Experiencing Touch by Technology

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Abstract. Touch technology can mediate social touch in situations when people cannot be physically close. Recent social touch technologies use haptic actuators capable of displaying pressure touch. We studied experience in two set-ups which use such actuators: a motorized ribbon and a McKibben sleeve. We investigated whether there is an inherent emotional and sensory experience attached to sensations produced by those set-ups. Participants were presented with pressure touches varying in rate of force change, peak force and contact area. Participants rated the sensory and emotional experience of each stimulus variation with a check-all-that-apply measure of 79 items in two sections and the Emoji-grid. We found that force has a major effect on the experience of a passive pressure touch. Speed and width also played a role, but to a lesser extent and only in one of the set-ups. The results inform the design of mediated social touch applications in making the technology more congruent with the context.

Keywords: Passive touch · Mediated social touch · Touch experience

1 Introduction

Social touch plays a key role in close social relationships. However, distance and social isolation create barriers for social touch. Touch deprivation might lead to loneliness [4]. The negative effects of touch deprivation can be partially mitigated by mediating social touch through technology [14]. Social touch technology (STT) is in continuous development. To inform this development, we studied user experience arising from technology-produced passive touch on the arm. Our findings can make mediated social touch more pleasant and acceptable.

The arm is one of the most comfortable and socially acceptable areas for receiving touch [12]. The arm is also suitable for mediated social touch, because it is easy to fix a device on the arm and to adjust fit to the user parameters. Therefore, a large proportion of STT is designed for use on the arm.

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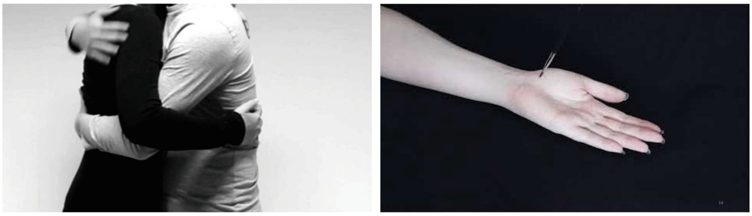

Fig. 1. Example stills of the videos shown during the interview (Videos 1, 5, and 9 from [7]. The custom videos are archived under DOI: 10.17632/9s6c2rzz8t.1)

STT can be based on vibration, force and temperature actuators [5]. More recent developments in STT focused on actuators that can produce pressure. Pressure actuators use different technologies: from tension bands [10], to pneumatics [17], to electroactive textile [8]. As pressure-based STT is being developed, more research is needed to determine what type of pressure would be most suitable to mediate social touch from the user perspective.

Limited guidance exists on factors that contribute to how users experience technology-produced sensation of pressure. Investigating the experience of touch with users is key to user-centred design. Tactile stimuli might have an inherent meaning or emotional associations. Although these associations will be modified by context [1], we must be aware of them to design a congruent experience.

In this study, we compared two actuators: a motorized ribbon, and a McKibben sleeve [16]. We investigated the effect of three actuator parameters - the peak force, the rate of force change, and the surface area with two levels each - on the sensory and emotional experience of the users. User experience was assessed through a multiscale experience profiling method (MEP method). The results can inform future STT design.

2 Study 1. Interviews for the Experience Profiling

The goal of this study was to identify a semantic field of expressions describing passive touch to develop the MEP method that will be applied in Study 2.

Participants. Since the experience of touch may depend on cultural background we performed semi-structured interviews with one participant from Sweden, one from Iran and one from China. The varying backgrounds provided a varied sample and starting point for the MEP method. All participants were interviewed in their own language. Interviews were conducted online. Before the interview started, participants read and agreed with an informed consent.[1] The participants received no payment.

Apparatus. Before the interview the participants were asked to do a brainstorm exercise designed to help them access their vocabulary on touch. The participants

[1] The research was reviewed and approved by the ethics committee of the EEMCS faculty of the University of Twente (reference RP 2020-104).

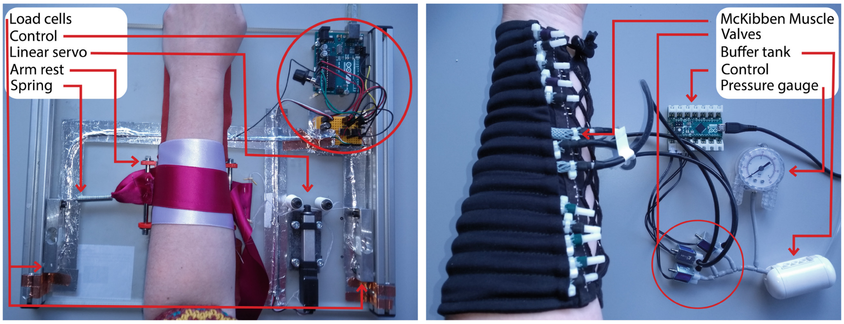

Fig. 2. The motorized ribbon on the left (the spring constant = 1.18 N/2 times the servo extension), the McKibben sleeve on the right

were shown touch videos from the socio-emotive touch database [7] and custom made videos of touch by objects [15] with the instruction to focus on the passive touch in the interaction. Figure 1 depicts stills taken from both types. Three videos of each category were shown and each video had a duration of two to eight seconds. The videos were viewed in the (online) presence of the interviewer. After each video, participants were asked eight open questions about the touch. The original interview questions were in English [15] and translated by interviewers to their native language. All conducted interviews were transcribed and translated to English for analysis[2]. The interview was semi-structured and took 45 min.

Results. We used grounded theory to analyze the interviews [6]. We found the following nine categories: Dynamic Properties (type, speed), Tactile properties (type, texture, localization, wet/dry), Comfort (mental/physical), Pain, Effect of the touch, Timbre, Affect, Bigger meaning and Context. For the development of the MEP method, we selected words in the categories most relevant to the emotional and sensory experience: Dynamic properties, Tactile properties, Effect of the touch, and Timbre. We limited the number of words to not overload the participants.

3 Study 2. Experience Profiling for Pressure Stimuli

Participants. A total of 52 students (local and international) and university staff members participated in study 2[3], 24 (age range 18–47, mean age 27.5, 9 females) experienced the ribbon set-up and 28 (age range 19–47, mean 25.5, 14 females) the McKibben set-up. Participants received a 5 Euro giftcard.

Apparatus. We used two set-ups to generate pressure stimuli on the lower arm: a motorized ribbon (Fig. 2, left) and a McKibben sleeve (Fig. 2, right) [16].

[2] Thanks Carin Backe, Hamid Souri and Fengdi Li for conducting the interviews.
[3] The research and Covid-19 precautions were reviewed and approved by the ethics committee of the EEMCS faculty of the University of Twente (reference RP 2021-200).

Table 1. The parameter settings for each set-up. The forces are for an arm circumference of 19 cm. AL denotes the length of the actuator in contact with the arm.

	Motorized Ribbon	McKibben Sleeve
Peak force (low, high)	6.3 Kpa, 24.8 Kpa (small area) 0.5 Kpa, 1.6 Kpa (large area)	5.6 Kpa, 8.9 Kpa
Rate of force change (slow, fast)	3027 ms, 1766 ms (low force), 4457 ms, 2724 ms (high force)	464 ms, 334 ms (low force), 496 ms, 453 ms (high force)
Surface area (small, large)	3 mm × AL, 40 mm × AL	13 mm × AL, 39 mm × AL

Motorized ribbon. A ribbon is wrapped around the arm on an armrest. A second ribbon is below the first to prevent the sensation of shifting. The ribbon is tightened around the arm using a linear motor that pushes the thread tied to the ribbon between two vertical rollers. The thread runs through ball bearings to reduce the amount of friction and lateral forces on the skin. The force on the arm is calculated by measuring the contraction force at two ends.

McKibben sleeve. The sleeve has 13 tunnels with McKibben actuators inserted with an average width of 13 mm each. McKibben actuators have a braided mesh outer sleeve and an elastic inner tube. When pressurized air enters the inner tube it expands. The longitudinal stiffness of the braided outer sleeve limits its increase in diameter causing linear contraction and creating pressure on the arm.

Stimulus parameters. In each set-up, we varied three stimulus parameters: the peak force, the rate of force change, and the surface area with two levels each. The eight stimuli for each set-up were presented three times to the participant. Table 1 summarizes the parameter settings for each set-up.

MEP Method. User interviews combined with literature research was our approach to create a check-all-that-apply (CATA) list [9]. We used the results of Study 1 and the work by [3] (lists with sensory and emotional properties of touch experience) to create two CATA lists: one for sensory and one for emotional qualities (understanding, happy, exciting, endearment, comforting, uplifting, thrilling, gentle, human, shocking, sexy, delicate, social, frightening, sensual, loving, mechanical, annoying, pleasurable, supportive, non-social, sad, desirable, friendly, surprising, upset, comfortable, aggressive, calming, irritating, relaxing, frustrated, dreadful, arousing, soothing, fleeting, pressing, smooth, dull, shaking, poking, rough, sharp, vibrating, slow, soft, hot, hitting, fast, flexible, cold, dragging, fluid, rubbery, lukewarm, tickling, itchy, tough, wet, stretching, friction, pointy, dry, patting, stinging, wrinkled, comfortable, squeezing, burning, textured, uncomfortable, embracing, flat, elastic, painful, tapping, hard, non-elastic, not painful). We added an option for not feeling touch, since sensitivity varies per person, and pilots showed that a slow rate of force change may be difficult to perceive. We also added the items human, mechanical, social and non-social, to measure if the touches are considered inherently social or human. In addition, we used the emojigrid [13] for the participant's rating of valence and

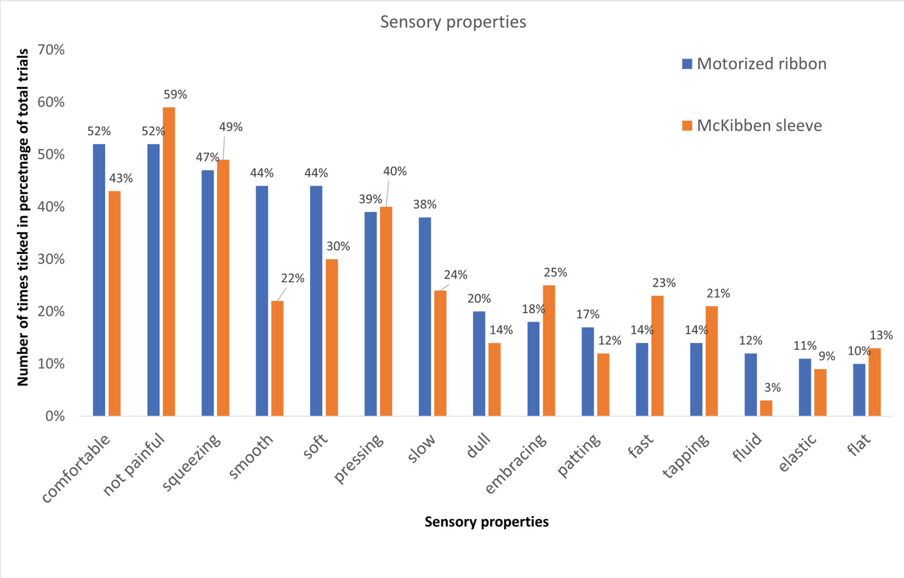

Fig. 3. Sensory properties for the motorized ribbon and the McKibben sleeve

arousal of each stimulus. These three parts combined allow us to broadly explore the touch qualities while keeping the effort for the participants acceptable.

Procedure. The participant's arm was placed in the set-up such that the middle between wrist bone and elbow was positioned under the ribbon, at this position the circumference was measured. The experiment was self-paced. After a signal by the participant a stimulus was presented followed by a part of the MEP method. The stimuli and the parts of the MEP method were presented in a randomized order. All three parts were completed before randomizing the next stimulus.

Results. Data of one participant from the McKibben sleeve experiment had to be deleted due to a technical error.

Sensory Properties. The frequencies of selecting each adjective across all trials are presented in Fig. 3 for all adjectives that were mentioned in at least 5% of the trials. As Fig. 3 shows, overall the participants experienced "comfortable", "non-painful", "squeezing", "smooth", "soft", and "pressing" sensations (mean percentage $> 25\%$), which is in line with our expectations. Not one single trial felt "painful". The McKibben sleeve was less often characterized as "smooth", "soft", "slow", and more often as "fast", "tapping".

In order to assess whether the frequencies were affected by each of the stimulus parameters, independent t-tests with 1000 bootstraps were performed for frequencies as dependent variable and surface area, peak force, and rate of force change as independent variables. The bootstrapping was used because the

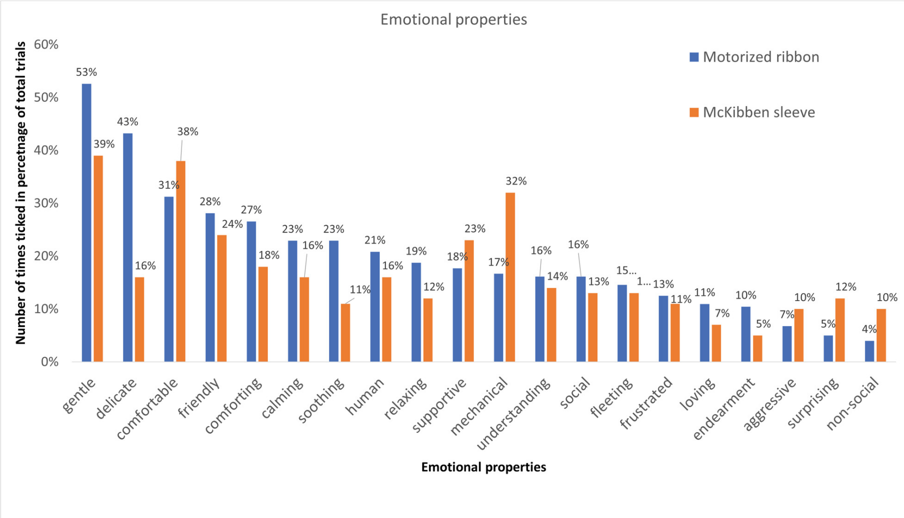

Fig. 4. Emotional properties for the motorized ribbon and the McKibben sleeve

assumption of observation independence does not hold for the trials, and the sample is very small. We did not correct for multiple testing because of low power and a high probability of Type II error. Since generalising to population is not the goal of the study, power concerns are favored over the risk of Type II error.

For the motorized ribbon, surface area showed no effects. Trials with higher peak force were perceived significantly more often as "squeezing" ($t(3.12) = -4.05$, $p = .025$), "embracing" ($t(4.09) = -5.17$, $p = .006$) and "rubbery" ($t(6) = -2.611$, $p = .040$), while trials with lower peak force were perceived more often as "flat" ($t(6) = 4.33$, $p = .005$) and "dull" ($t(6) = 2.53$, $p = .044$). Trials with a higher rate of force change were perceived more often as "fast" ($t(6) = -9.02$, $p = .000$).

For the McKibben sleeve, small surface area was more frequently described as "patting" ($t(6) = 4.92$, $p = .003$) compared to large surface area. Trials with high peak force were more often described as "slow" ($t(6) = -3.27$, $p = .017$), "itchy" ($t(3) = 5.0$, $p = .015$) and "uncomfortable" ($t(6) = -3.0$, $p = .024$) compared to lower peak force trials. Rate of force change showed no significant effects.

Emotional Properties. The frequencies of selecting each adjective across all trials are presented in Fig. 4 for adjectives mentioned in at least 5% of the trials. Overall the touch by the motorized ribbon elicited "gentle", "delicate", "comfortable", "friendly", "comforting" emotional experiences (mean percentage > 25%). McKibben sleeve seemed to elicit less delicate or gentle, and more mechanical emotional experiences.

The effects of surface area, peak force, and rate of force change were assessed in the same way as the sensory properties adjectives.

For the motorized ribbon, surface area showed no effects. Trials with high peak force were more frequently described as "endearing" ($t(6) = -3.46$, $p = .013$), "supportive" ($t(6) = -3.14$, $p = .02$), "comforting" ($t(6) = -2.56$, $p = .043$), "social" ($t(6) = -2.53$, $p = .001$) and "human" ($t(6) = -6.48$, $p = .001$), but also more frequently as "aggressive" ($t(6) = -5.75$, $p = .001$) and "upset" ($t(6) = -3.27$, $p = .017$). Low peak force was more frequently described as "delicate" ($t(6) = 2.64$, $p = .038$) and "fleeting" ($t(6) = 2.9$, $p = .027$). Trials with higher rate of force change were more frequently described as "mechanical" ($t(6) = -3.69$, $p = .01$).

For the McKibben sleeve, small and large surface area trials resulted in similar experience profiles. Higher peak force trials were less frequently described as "delicate" ($t(6) = 5.29$, $p = .0.002$) and more often as "frustrated" ($t(6) = -3.38$, $p = .0015$), "fleeting" ($t(6) = -2.53$, $p = .0045$), "exciting" ($t(6) = -2.45$, $p = .05$) and "loving" ($t(6) = -2.45$, $p = .05$). Trials with higher force change rate were more often described as "surprising" ($t(3) = -7$, $p = .006$), and less often as "calming" ($t(6) = 2.65$, $p = .038$) or "understanding" ($t(6) = 2.78$, $p = .032$).

Valence and Arousal. To access the emotional experience reflected in EmojiGrid, a 3×2 repeated measures MANOVA was performed with surface area, peak force, and rate of force change as within-subject independent variables, the scores for the dimensions of valence (x-axis) and arousal (y-axis) as two dependent variables. The scores varied between 0 and 220 for both axes.

For the motorized ribbon peak force had significant effects on emotional experience measured by the EmojiGrid, Wilk's lambda = .54, $F(2, 22) = 9.45$, $p = .001$. Surface area had a marginally significant effect, Wilk's lambda = .76, $F(2, 22) = 3.43$, $p = .051$.

The univariate tests further revealed that arousal score was higher for larger surface area ribbon ($M = 135.5$) compared to smaller surface area ribbon ($M = 118.9$), $F(1, 23) = 6.04$, $p = .022$. The peak force also effected arousal so that the arousal score was lower for trials with higher peak force ($M = 114.2$) compared to trials with lower peak force ($M = 140.2$), $F(1, 23) = 18.64$, $p < .001$. There were no effects of surface area or peak force on the valence axis score.

For the McKibben sleeve, peak force, Wilk's lambda = .72, $F(2, 25) = 4.96$, $p = .015$, and rate of force change, Wilk's lambda = .65, $F(2, 25) = 6.67$, $p = .005$, had significant effects on emotional experience measured by the EmojiGrid. The univariate tests further revealed that peak force had an effect on both valence and arousal scores. Trials with higher peak force resulted in less positive emotional experience ($M = 123.8$) compared to trials with lower peak force ($M = 141.4$), $F(1, 26) = 8.68$, $p = .007$. Peak force also effected arousal so that the arousal score was lower for trials with higher peak force ($M = 117.1$) compared to trials with lower peak force ($M = 129.8$), $F(1, 26) = 4.90$, $p = .036$. The rate of force change effected the valence so that emotional score was more positive for lower rate of force change ($M = 140.4$) compared to higher rate of force change ($M = 124.6$), $F(1, 26) = 13.80$, $p = .001$. There were no effects of the rate of force change on the arousal axis score, $F(1, 26) = 1.90$, $p = .176$.

4 Discussion and Conclusion

We examined whether inherent meanings are associated with pressure presented to users' arms without any context. Several conclusions follow the results.

(1) We find that perceptions covary systematically with the properties of the stimuli. Therefore, there seems to be inherent meanings associated with different stimulus properties. (2) The two actuators seem to produce comparable experiences. Four of the top-5 sensory experiences for the two actuator types overlap (i.e., "comfortable", "not painful", "squeezing", and "soft"), and three of the top-5 emotional experiences ("gentle", "comfortable", and "friendly"). However, there are also differences in the profiles that may be related to the (confounding) parameter settings. Looking at the differences: the McKibben sleeve elicited less delicate, less gentle, and more mechanical emotional experiences in comparison to the motorized ribbon. The difference could be due to the fact that both rate of force change settings were faster than the motorized ribbon speed settings. This is supported by the findings that trials with higher rate of force change of the motorized ribbon were also more frequently described as mechanical. (3) In our studies for both set-ups higher peak force was more often perceived as comforting, social, and human. This is in line with previous findings that substantial pressure can have comforting and calming effects [2,11]. High peak forces tend to evoke more emotions and are more comfortable, thus are more suitable for STT. Pressure needs to be high enough to have a calming, comforting effect, but not become uncomfortable. The drawback is that valence of such pressure can vary depending on context, so the context must be chosen carefully.

Overall, the results suggest that it might be easier to produce a delicate, smooth, soft and calming sensation with the motorized ribbon than with the McKibben sleeve and thus be preferable for creating comforting social touch, at least with the conditions that we set for our investigation. More importantly, our findings suggest that every specific technology should be tested for inherent meanings and associations, so that stimuli are appropriately aligned with the context for the congruence of experience.

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