Stretching Time With Velvet: How Affective Materials Shape Our Perception of Time

Müge Cavdan and Knut Drewing

***Abstract*—Research has shown that affective visual and auditory events (e.g., a crying baby) are perceived as lasting longer compared to neutral ones. However, the impact of affective haptic experiences on time perception has hardly been studied. This study investigates the influence of interacting with affective materials on time perception. We selected three materials that are known to evoke pleasant (velvet), unpleasant (sandpaper), and neutral (paper) affective responses. Participants completed a temporal bisection task to assess how each material influenced their perception of time. The task involved presenting the materials in time intervals from 1000 to 2200 ms in 200 ms increments. In each trial, a participant stroked one of the materials, with the duration being limited by two vibrotactile feedback, and judged whether the duration felt closer to a previously learned short or long interval. Expectedly, velvet yielded lower bisection points than paper. Contrary to expectations, bisection points for sandpaper – despite being an unpleasant material – did not significantly differ from that for the control material, paper. These findings suggest that while pleasant haptic material experiences can extend perceived time, unpleasant materials may not have an effect. This effect is partially consistent with the observed time lengthening during affective auditory and visual events.**

***Index Terms*—Affective touch, haptics, time perception, timing.**

I. Introduction

Time perception plays an important role in human experience shaping how we interact with the world, make decisions, and perceive our environment. The ability of timing is inherently subjective and depends highly on various psychological factors including the available sensory information [1], [2], [3], or attention [4], [5]. Numerous studies have shown that particularly affect and affective stimuli influence time perception [6], [7], [8]. Affective events are often perceived to last longer than neutral events of the same physical duration (e.g., [6], [9], [10]).

Awe-inducing stimuli have been shown to distort time perception [6]. Specifically, individuals perceive awe-inducing landscapes as lasting longer compared to neutral scenes. This time dilation effect is also observed with other affective stimuli, such as sounds that evoke strong responses (e.g., a crying baby or siren) [9] which are judged to last longer than neutral sounds. Similarly, facial expression of anger are perceived as lasting longer than neutral expressions [11], [12], [13].

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This work involved human subjects or animals in its research. Approval of all ethical and experimental procedures and protocols was granted by Local Ethics Commitee of Faculty 06 at the Justus Liebig Unicersity Giessen under Application No. 2022-003, performed in line with the Decleration of Helsinki.

The authors are with the Experimental Psychology Department, Justus Liebig University Giessen, 35390 Giessen, Germany (e-mail: Muege.Cavdan@psychol.uni-giessen.de).

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Aforementioned findings underscore the importance of affective stimuli in time perception, but existing research mainly focused on auditory and visual domains. Only a few studies investigated haptic experiences with a focus on the role of affective information on tactile time perception [14], [15] showing that neutral tactile time perception can be influenced by emotional stimuli presented simultaneously in other modalities. This gap in the literature exists, despite haptic experiences playing a central role in our everyday experiences. From the moment we wake up and interact with the fabric of our bedding to the devices, tools, and materials we handle throughout the day, our haptic environment is a constant source of sensory input. These materials not only serve functional purposes but also evoke affective responses that can in turn influence our perception of time.

While time perception of haptic affective material qualities has, to our knowledge, not been studied, their broader impact on human experience has long been recognized [16], [17]. Researchers have explored the relationship between material properties like roughness [18], [19], [20], [21] and softness [16], [22], and their perceived pleasantness. Findings suggested that soft and smooth textures feel pleasant while stiff, coarse, and viscous materials are considered unpleasant [23]. Studies using naturalistic materials like fur, sandpaper, and sand [24], [25], [26], [27] expended our understanding of haptic experiences consistently showing soft materials (see the definition of softness [28], [29]) like fur [26], sand [26], and velvet [27] felt pleasant while rough and viscous materials such as coarse sandpaper [19], and hand cream [23] felt unpleasant.

Given the established role of affect in visual and auditory time perception, it is plausible that haptic interactions with materials would produce similar effects on subjective time. However, to our knowledge, there is so far hardly systematical research on this topic. The present study explores how interacting with materials evoking affective responses influences time perception. In doing so, we introduce and validate a novel method for studying haptic material perception in relation to temporal judgments.

We selected three materials known to elicit affective and neutral responses: velvet (pleasant) [27], sandpaper (unpleasant) [30], and paper (neutral) [31] which are widely used in affective haptic material literature. Participants performed a temporal bisection task where they stroked one of these materials and judged whether the duration of the haptic experience felt closer to a short (1000 ms) or long (2200 ms) anchor duration they had learned earlier. The experiment comprised of two groups: affective and control. In the affective group, participants stroked and timed the duration of affective materials in a random order. In the neutral (control) group, participants completed the temporal bisection task using the neutral material followed by rating the pleasantness and arousal of all materials. The affective judgements were only collected from a subset of participants because these affective responses had already been observed in previous research [27], [30], [31]. The neutral condition served as a baseline for comparing the time perception of affective materials. While a baseline without movement might seem more controlled, self-generated movements influence time perception by slowing down the perceived duration of events [32], [33]. To ensure consistency, participants performed the same stroking motion with the neutral materials as with the affective ones. This design minimizes potential carryover effects and ensures that observed difference reflect affective material qualities rather than prior exposure or learning effects.

To validate our material choice, we first assessed how pleasant and arousing each material felt. We hypothesized that the two affective materials (velvet and sandpaper) would differ in pleasantness compared to the neutral material (paper). Specifically, velvet was expected to be the most pleasant, followed by paper, and sandpaper was anticipated to be the least pleasant. We also hypothesized that the affective materials would be more arousing than the neutral material, with no significant difference between velvet and sandpaper. Importantly, based on prior research on visual and auditory stimuli, we hypothesized that affective materials would be perceived as lasting longer than neutral materials. In that, we expected stroking velvet and sandpaper for the same duration would feel longer than stroking paper. However, we did not have a specific hypothesis for the comparison between sandpaper velvet, given the conflicting findings in timing literature regarding pleasant and unpleasant events (e.g., [1], [9]).

II. Methods

A. Participants

A priori power calculation was used to determine the sample size. The projected sample size based on a large effect [8], [9], [14] (Cohen's $d = .7$), 80% power, and an alpha of 5% for a one-sided independent-samples t-test was 26 [34]. Accordingly, data from 27 participants were collected for both affective (8 males, $M_{age} = 26.26$, age range = 21–39 years) and control (8 males, $M_{age} = 25.19$, age range = 18-36 years) groups, resulting in a total sample size of 54 right-handed participants. Recruitment was carried out via circular university emails. None of the participants reported any sensory or cutaneous problems. The two-point discrimination threshold at the index finger of the right hand (i.e., dominant) was 3 mm or better. The methods are approved by the Local Ethics Committee of Faculty 06 at the Justus Liebig University Giessen which are performed following the Declaration of Helsinki [35] without preregistration. Prior to the experiment, participants provided written informed consent and were compensated 8€ per hour for their time upon completion.

B. Stimuli and Apparatus

Based on previous research we selected three materials that would feel pleasant, unpleasant, and neutral which are velvet [27], sandpaper [19], [30], and paper [31] respectively. All materials were mounted on a 10 cm × 10 cm wooden block, covering the wood. Sandpaper was 150 µm in grain size, velvet was made of 100% polyester (weight 160 g/m^2), and paper was a regular printing paper (weight: 80 g/m^2, see Fig. 1 upper panel). Since sandpaper and paper could change their structure upon exploration, they were replaced with new samples after every five participants. The affect of the materials was measured with two 7-point scales for valence (how pleasant was the material: 1 – *very pleasant* 7 – *very unpleasant*) and arousal (how exciting was the material: 1 – not exciting at all 7 – extremely exciting).

A custom-made setup was used to present the vibrotactile feedback. The feedback was provided with a cylindrical rotating mass actuator (VZ7AL2B1690002; Vybronics Ltd.) which is placed in a custom-made encapsulation (Fig. 1 bottom right) [14]. The actuator specifications were as follows: 7 mm diameter, 16.5 mm body, 2.2 ∼ 3.6 operating voltage, 250 mA maximum current, and 7.3 gravitational maximum force. A DRV2605L motor driver (Texas Instruments) drove the actuator which was controlled with an Ardunio Uno Revision 3 and

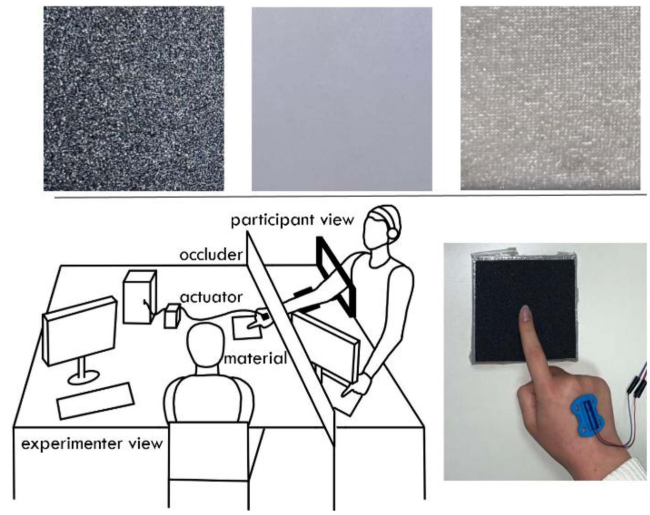

Fig. 1. Materials (sandpaper, paper, and velvet respectively) and the experimental setup used in the experiment. The participant's hand was placed on an armrest to ensure comfortable exploration, and an actuator was positioned on the back of the right hand, as detailed in the bottom right.

a custom script. Vibrotactile feedback with 2.52 m/s^2 amplitude and 85 Hz frequency was used.

Active noise-canceling headphones (Sennheiser HD 4.5 BTNC) were used to eliminate any sounds caused by the actuator and to additionally deliver a neutral noise (i.e., river sound). A fabric occluder was used to prevent the materials being visible to the participants. The experiment was programmed in MATLAB 2022a using Psychtoolbox routines [36]. A standard keyboard was used to collect the participant responses and a monitor to present the instructions.

C. Design and Procedure

A mixed design was used where half of the participants completed the temporal bisection task for velvet and sandpaper (*affective group*) while the other half completed bisection for the paper and afterwards evaluated all three stimuli for valence and arousal (*control group*). Prior to the experiment, a two-point touch task was conducted using a two-point discriminator, consisting of two plastic disks with touch patterns consisting of rounded tips. The tip configurations included a single-tip configuration and two-tip configurations with inter-tip distances from 2 to 8 mm. The experimenter applied only the single-tip and two-tip patterns with distances from 2 to 4 mm as a threshold equal to or above 4 was desired. Each pattern was applied three times in a random order and participants indicated whether they perceived one or two tips. All participants were able to discriminate all the tips at a distance of at least 3 mm, with overall 99% accuracy in their responses.

The temporal bisection task involved learning first two anchor durations: long (2200 ms) and short (1000 ms) presented to the to the lower back of the right hand (i.e., in between carpal bones and metacarpal bones, see Fig. 1) as an interval marked by two 100 ms vibratory stimuli at the start and end of the interval. Each learning trial began with a 500 ms fixation cross on the screen, signaling participants to focus on the task. Then the unfilled interval was presented and followed by feedback on the screen indicating whether the interval was long or short. Each duration was presented six times in a random order (twelve trials). To test whether the individuals indeed learned the durations, a short learning check followed. Similar to the learning phase, a 500 ms fixation was followed by an interval of either long or short duration.

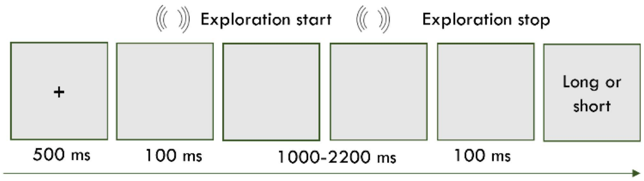

Fig. 2. Time course of the testing trials in the temporal bisection task.

Individuals indicated whether the duration was long or short by pressing the right or left arrow on the keyboard. Upon responding, feedback on the correctness followed. If a participant made more than 20% errors, they were required to repeat the learning phase. However, no participant needed to repeat this phase with an average accuracy of 97.4% (range: 83.3-100).

After the learning phase, participants proceeded to the test phase (Fig. 2). In each trial, a 500 ms fixation cross was followed by a vibration signaling the individuals to start stroking a surface with their right index finger. The stroking continued until a second vibration signaled the end of the trial. The durations that individuals had to explore and time were 1000, 1200, 1400, 1600, 1800, 2000, and 2200 ms. During this period, participants were instructed to maintain continuous contact with the surface, avoiding lifting their finger until the exploration time elapsed. If they reached the edge of the stimulus, they were required to change direction and continue stroking until the trial ended. Each duration was presented for 12 times resulting in 84 trials in total per material (12 repetitions $\times$ 7 durations). Participants in the affective group completed 168 trials in random order (84 for sandpaper and 84 for velvet) while the others completed 84 trials. Participants in both affective and control groups had at least two-minute break after completing half of the trials.

Upon completion of the temporal bisection task, the individuals in the control group responded to the questions about affective properties of the material. Blindfolded, they were presented with the materials in random order and asked to rate their experience of the material in terms of valence and arousal. The experiment took approximately 60 minutes to complete for the affective group and about 45 minutes for the control group including the welcoming, instructions and the training.

D. Data Analysis

In order to confirm our assumptions on affective surface properties, we first conducted a repeated-measures analysis of variances (ANOVA) to compare the valence responses of the individuals for each material (i.e., velvet, sandpaper, and paper). Another ANOVA tested whether there was an arousal difference between materials. Both ANOVAs were followed with Holm-corrected t-tests to investigate the difference within material pairs [37].

For the timing data, we first calculated the proportion of long responses from the raw data per exploration duration from the test phase separately for each participant. Next, we fitted logistic psychometric functions using the proportion long responses with the Psignifit 4 toolbox [38] for each individual. Lower and upper asymptotes were fixed at 0. The beta prior was held constant at 0.01 to allow the data to determine the shape of the psychometric functions. The goodness-of-fit values were comparable across materials ($M_{paper} = 7.09$, $M_{sandpaper} = 8.55$, and $M_{velvet} = 8.13$). This suggests that the psychometric models fit equally well across all materials. The Bisection Points (BP), also referred to as the Point of Subjective Equality (PSE), were calculated as the duration with a 50% probability of a long response, the Just Noticeable Difference (JND) was half of the difference between stimulus levels where long responses were 25% and 75% of the cases. The ratio between JND and BP defines the Weber Fractions (WF). To test the effect of material on time perception, we used two independent sample t-tests to compare paper with sandpaper and with velvet and a paired-sample t-test to test any difference between velvet and sandpaper.

The length of the experiment in the affective and control groups differed, with the experiment lasting longer for affective group. Some studies suggest that, when experiments take longer, people are more likely to perceive time intervals in each trial as long [39]. Although we kept the experiment relatively short to minimize such effects, we tested this possibility by examining the proportion of long responses by randomly selecting half of the trials in the control condition and compare to the first half of the trials in the affective conditions. By focusing on these trials, where the influence of boredom, accumulated duration, or even fatigue is distributed randomly or would not be expected to exist, we aimed to determine whether the observed longer responses in the affective condition were genuinely related to the affective material itself or simply a consequence of accumulated duration effects. To this end, for each participant, first half of the trials for affective materials and a random half of the control trials were selected and included in the analyses. From these trials we calculated the mean proportion of long responses for each participant and material. These values are then submitted to t-tests to test the effect of material on time perception as in the previous initial analyses.

All analyses were conducted in JASP (v016.2.0) and figures are plotted in MATLAB 2022b.

III. Results

A. Unpleasantness and Arousal of the Surfaces

Confirming our hypotheses, Holm-corrected t-tests showed that sandpaper felt more unpleasant than velvet ($t(26) = 9.84$, $p < .001$, $d = 1.89$, one-sided) and paper ($t(26) = 8.06$, $p < .001$, $d = 1.55$, one-sided). Also, velvet felt more pleasant than paper ($t(26) = -2.25$, $p = .02$, $d = -.43$, one-sided).

Expectedly, Holm-corrected t-tests showed sandpaper ($t(26) = 2.91$, $p = .004$, $d = .56$, one-sided) and velvet ($t(26) = 3.41$, $p = .001$, $d = .66$, one-sided) were more arousing than paper. However, sandpaper and velvet were not significantly different in terms of arousal ($t(26) = -.08$, $p = .94$, $d = -.02$, two-sided).

B. Timing of the Surfaces

The proportion of long responses revealed lengthened time perception for velvet compared to paper ($t(52) = 1.91$, $p = .03$, $d = .52$, one-sided). However, sandpaper did not lengthen time perception compared to paper ($t(52) = 1.18$, $p = .12$, $d = .32$, one-sided) and velvet ($t(26) = -1.42$, $p = .17$, $d = -.27$, two-sided).

Velvet resulted in shorter BPs than paper ($t(52) = -1.80$, $p = .04$, $d = -.49$, one-sided) expectedly while sandpaper did not result in significantly shorter BPs than paper ($t(52) = -1.02$, $p = .16$, $d = -.28$, one-sided). Sandpaper did also not result in significantly different BPs compared to velvet ($t(26) = 1.7$, $p = .10$, $d = .33$, two-sided).

Finally, to test the stability of the WFs across conditions, we performed three t-tests. Velvet ($M = .16$, $SD = .01$) did not significantly differ from paper ($M = .16$, $SD = .04$; $t(52) = -.56$, $p = .58$, $d = -.15$) revealing similar sensitivity. However, sandpaper ($M = .14$, $SD = .01$) had a significantly smaller WF than paper ($t(52) = -.2.33$, $p = .02$, $d = -.64$) and velvet ($t(26) = -3.95$, $p < .001$, $d = -.76$).

C. Potential Influence of Experiment Duration on Time Perception

The comparison between first half of the trials in the affective condition with the random half of the trials from the control condition revealed findings consistent with those for the whole experiment. The proportion of long responses was greater for velvet compared to paper: $t(52) = 1.73$, $p = .045$, $d = .47$, one-sided. However, sandpaper did not significantly differ either from paper or velvet: $t(52) = 0.77$, $p = .22$, $d = .21$, one-sided; $t(26) = -1.44$, $p = .16$, $d = -.28$, two-sided, respectively.

IV. Discussion

We interact with materials varying in pleasantness on a daily basis. The affective value associated with these materials can influence how we perceive the time. In the present study, we demonstrated that the pleasant material, velvet, lengthened time perception compared to neutral material, paper. Interestingly, sandpaper, despite being unpleasant, did not significantly influence time perception compared to paper. These results contribute to the growing body of literature focusing on the effects of affective tactile experiences on time perception [14], [15] by expanding research into active haptic interaction with materials. Notably, analyses of the random (control) and first half (affective) of the trials were consistent with the findings for the entire experiment, providing robust evidence that the effect is driven by the material qualities themselves rather than confounds such as boredom, fatigue, or the overall duration of the experiment. Overall, by establishing a foundational framework, our work also provides a starting point for future research to explore a broader range of materials and refine our understanding of how affective haptic materials modulate time perception.

Consistent with previous research on affective stimuli in the visual [1], [9], [12] and auditory domains [9], pleasant material lengthened perceived time compared to neutral material. However, sandpaper did not show such an effect. Sandpaper was not significantly different from either paper or velvet, suggesting an intermediate effect with a mean value between the two (see Fig. 4). In the current study, the valence value for paper (2.5 in a scale of 1-7) seems to indicate a slight pleasantness rather than complete neutralness. This suggests that participants may not have perceived paper as entirely neutral, which could have influenced their timing judgments. As a result, the lack of significant difference between sandpaper and paper might, in part, be due to paper's mild pleasantness rather than true neutralness.

It is also possible that sandpaper exerts some influence on time perception, but the effect might be too subtle to reach significance in the current study. This unexpected lack of effect cannot be explained by the arousal difference between sandpaper and velvet as they both evoked relatively similar and rather low arousal levels (see Fig. 3). In the broader context of affect and time perception, several studies have emphasized the critical role of arousal in driving temporal distortions [9], [10], [12], [40], [41]. However, while arousal might be a very important factor for unpleasant surfaces in time perception, this may not be the case for pleasant surface. Affect is complex and temporal distortion can be better understood while considering its complex nature which is not solely determined by arousal levels but also its direction (i.e., valence). In our study, both velvet and sandpaper were rated as relatively low-arousing stimuli, and this may explain the different outcomes in time perception. Velvet, as a pleasant material, may have been more likely to engage attentional resources in a way that caused individuals to overestimate time, consistent with previous findings on pleasant low-arousal stimuli [1]. On the other hand, sandpaper, seems to

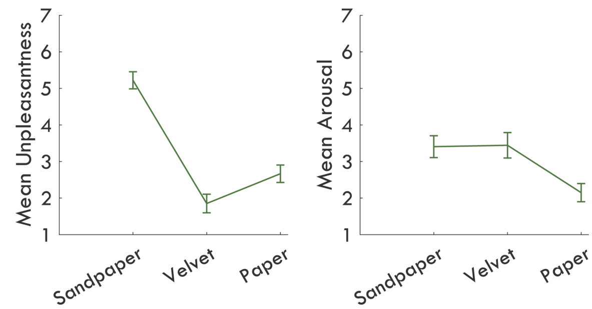

Fig. 3. Mean unpleasantness (left) and arousal (right) for the three textures: sandpaper, velvet, and paper. Higher values indicate greater unpleasantness (left) and higher levels of arousal (right). Error bars correspond to ±1 standard error of the mean.

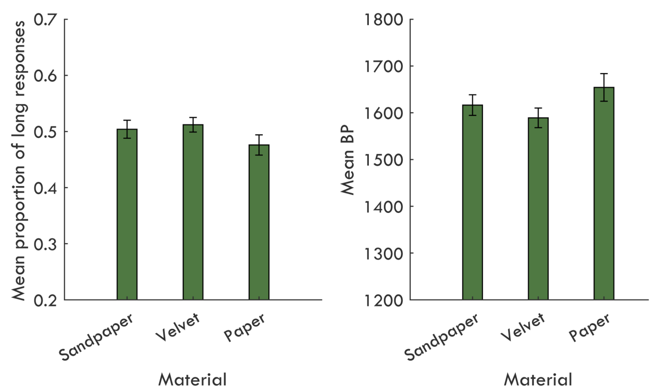

Fig. 4. Mean proportion of long responses (left) and bisection points (right) for sandpaper, velvet, and paper. Error bars correspond to ±1 standard error of the mean.

have not activated the defensive mechanisms that typically speed up the internal clock in high arousal and threatening situations. Instead, its low arousal and mildly unpleasant nature could have failed to significantly affect time perception. This aligns with results from our study where we investigated how affective vibrotactile information influences the time perception of subsequent events [42]. In that, high arousing vibrotactile patterns presented on the torso extended the perceived duration of subsequent events regardless of valence. More relevant to the present study, we also found that pleasant low-arousing events lengthened the duration of subsequent time judgements, whereas unpleasant low arousing patterns did not produce a similar effect. These results together suggest that the interplay between arousal and valence is a critical factor in how affective events influence time perception in tactile experiences.

These affective timing results in tactile and haptic perception coincides with the work of Angrilli et al. [1], who used images from the International Affective Picture System [43] and physiological measurements (e.g., skin conductance), to demonstrate how arousal and valence interact to influence time perception. Their findings revealed that under high-arousal conditions, unpleasant stimuli are overestimated. In contrast, under low-arousal conditions, the effects of valence on time perception are reversed – unpleasant stimuli leading to underestimation while pleasant stimuli resulting in overestimation relative to control (i.e., neutral condition). It is plausible to think that high arousal unpleasant events lengthen time perception by allowing an organism to prepare for a quick action. However, this need for fast acting may not be necessary for low-arousal unpleasant situations as they are not a deadly threat for an organism.

An alternative explanation for the lack of time lengthening in the unpleasant material might be related to the duration selection. We used relatively long time intervals (seconds range) in the active exploration task allowing individuals to fully engage with the materials. Shorter exploration durations might not have provided sufficient contextual information for participants to fully process the characteristics of the material. Previous studies have demonstrated that brief interactions ($\sim$1s) are sufficient to activate mechanoreceptive afferents [44] which have been found to provide affective information about materials during active material exploration with fingertips [45]. Given our exploration durations, participants likely had enough time to process both sensory and affective properties of the materials. The absence of time distortion with sandpaper could be attributed to this combined effect of prolonged exposure and low arousal. This is consistent with previous work suggesting that individuals tend to maintain pleasant states for longer periods compared to unpleasant states [46], [47], [48]. In the early stages of contact with sandpaper, participants may experience a brief affective response, however as the exploration continues, the affective salience of the material likely diminishes, leading to a neutralization of its impact on time perception. In contrast, we observed a persistent time distortion with the pleasant materials which might be due to the sustained nature of the pleasant state over time. Pleasant stimuli might evoke a prolonged sense of affect which remains throughout the interaction.

For example, Noulhiane et al. [9] found that emotional time distortion effects disappeared after approximately 4 seconds with auditory stimuli. This might have been the case with the unpleasant material such that the affective time influence may fade more quickly over time compared to the pleasant material. It is possible that the unpleasantness of sandpaper only distorts time perception in the early stages of exposure and this effect may have diminished over the longer exploration periods. In fact, in another study investigating affective time lengthening effects of tactile stimuli on subsequent neutral events, we found no effect for unpleasant low-arousal tactile information [42]. This pattern of findings supports the notion that low-arousal unpleasant stimuli might only cause brief, transient distortions in time perception, which quickly fade with continued exposure.

However, these findings should be interpreted with caution due to the limited range of materials used in the experiment. The study focused on three specific materials which may not fully represent the broad spectrum of tactile experiences. It is possible that the effects observed are material-specific affective or even timing effects and may not generalize to other types of pleasant and unpleasant textures. Future research should incorporate a broader variety of materials to further validate and refine the understanding of how haptic experiences influence time perception. Additionally, individuals' daily experiences with materials could influence their perception. For instance, someone who frequently uses sandpaper at work but enjoys their job might not find this interaction as unpleasant. This association could attenuate the typical unpleasant effect linked to sandpaper, potentially diminishing its impact on time perception. Therefore, personal context and affective associations with materials might play a crucial role in shaping how individuals perceive and process haptic stimuli. For instance, sandpaper could be replaced with a material of similar roughness but with more negative connotations, such as one associated with extreme discomfort, to explore whether this results in different effects on time perception. Systematically manipulating the connotative and contextual aspects of materials in future research would enhance our understanding of how affective materials, shaped by individual experiences and associations, interact with perceptual processes to influence temporal judgements.

To the best of our knowledge, this was the first study to investigate the time perception of affective haptic materials. This line of research has potential implications for various fields where haptic materials and time perception intersect. For example, in product design and material development, understanding how tactile pleasantness influences time perception can inform the generation of materials that improve user performance by modulating perceived time. In high risk environments, where quick and accurate decision making is needed, materials that naturally extend perceived time could enhance decision making process by allowing individuals to process the situation more efficiently. A lengthened sense of time during a critical situations might provide individuals a better window to assess their options [49].

V. Conclusion

This study provides new insights into the relationship between haptic material experiences and time perception. Our findings suggest that pleasant materials such as velvet can indeed extend perceived duration while unpleasant materials like sandpaper did not produce the similar time effect. However, these findings should be interpreted with caution, as the study used a limited range of materials to represent valence. Future research should involve more materials and also explore broader implications of our findings. For example, in practical contexts such as product design and marketing where haptic experiences can subtly influence consumer perception and behavior.

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