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The Impact of Velocity on Pleasantness Rating of Brush Stimulation vs. Apparent Haptic Motion

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Abstract. The pleasantness of brush stimulation as a function of velocity is linked to the activity of C-tactile (CT) afferents. Some studies have also found that Apparent Haptic Motion (AHM) can generate pleasant touch despite CT afferents not being sensitive to vibrations and that the contextual presentation of stroking velocities can modify the pleasantness of a caress. By comparing brush and AHM stimulations, this study examines whether the pleasantness of stroking at 3 cm/s depends on the speed of companion stimuli. Overall, the results show that brush stimulation is more pleasant than AHM but that 3 cm/s strokes are equivalent in pleasantness regardless of the accompanying stimuli speed.

Keywords: Pleasantness, Velocity, Apparent Haptic Motion, Brush stimulation

1 Introduction

Numerous studies have shown that moderate strokes/caresses (1-10 cm/s) are more pleasant than very slow (<1 cm/s) or fast (>20 cm/s) ones, which corresponds to the strength of the C-Tactile (“CT”) afferent activity (e.g., [1]). However, former studies involved a limited range of velocities (<5 velocities) and the way stroke velocities are presented could influence pleasantness rating [2]. For example, Triscoli et al. [3] discovered that there is a difference in pleasantness rating between 3 cm/s and 30 cm/s when these two velocities are presented together, whereas no significant difference are found when they are presented separately. Haptic vibrotactile devices can also simulate pleasant sensation as a function of velocity, for instance, through Apparent Haptic Motion illusion (“AHM”) [4], even though CT afferents are not sensitive to vibrations [5]. However, in a related study, Israr and Abnoui [6] did not find any impact of velocity, which could come from the specific velocities used. Moreover, the abrupt transitions in stroke speeds raise the question of how the pleasantness rating of stroke is influenced by the surrounding strokes arises. Finally, using AHM could clarify how pleasantness percept is formed and highlight differences between stimulations that activates CTs and those that do not. Therefore, the study reported here aims at investigating how the pleasantness of a stroke at 3 cm/s (for which the activity of CTs is the highest [1]) is modulated when it is accompanied either by a stroke associated to high (1 and 10 cm/s) or low (0.5 and 30 cm/s) CT activity, as well as the difference between brush stimulation and AHM to provide a more comprehensive understanding of affective touch.

2 Materials and methods

In the brush condition, strokes were delivered by a robotic arm with a soft brush on the skin's forearm (over 9 cm). In the vibrotactile condition, four voice-coils attached to the participant's forearm generated vibrotactile stimuli at 120 Hz using the Tactile Brush Algorithm [7]. The pleasantness rating was recorded using a visual analog scale with a slider ranging from 0 ("Unpleasant") to 100 ("Pleasant"). Twenty-four participants received alternatively series of strokes performed by a brush and vibrators. Once installed, the calibration phase started to reach a brushing force at 0.4 N and each participant had to adjust the intensity of AHM to be equivalent to the brush force by a method of adjustment. In the main experiment, after each stroke, participants had to rate their pleasantness. The dependent variable was the perceived *Pleasantness* while the 2 independent variables were: *Stimulation* (Brush or AHM) and *Companion velocity* (0.5, 1, 10, 30 cm/s), in which the velocity of reference (3 cm/s) was compared with the velocity of interest through four comparisons: 0.5-3, 1-3, 3-10, 3-30 cm/s. Eight different conditions (2 *Stimulation* x 4 *Companion Velocity*) of stroking were tested on each participant (96 strokes in total). The effects of *Companion Velocity* and *Stimulation* on *Pleasantness* of strokes at 3 cm/s were analyzed in RStudio by designing a Generalized Linear Mixed Model (GLMM), which was fit by the restricted maximum likelihood with Gaussian distribution. An ANOVA was conducted on fixed effects. Additionally, the effects of *Velocity* and *Stimulation* on *Pleasantness* were analyzed separately for each *Companion Velocity* using a GLMM. Post-hoc analyses were computed on significant fixed effects by using the package "emmeans" and pairwise comparisons were adjusted by Bonferroni's method.

3 Results and Discussion

The statistical test probing the effect of *Companion Velocity* and *Stimulation* on *Pleasantness* rating 3 cm/s strokes showed a significant effect of *Stimulation* ($F(1, 161) = 22.6, P < 0.0001$), the brush being significantly more pleasant than AHM ($P < 0.0001$) (Fig. 1A), whereas there was no effect of *Companion Velocity*. Moreover, tests conducted on the four GLMMs (*Velocity* and *Stimulation*) at each *Companion Velocity* showed a significant effect of *Velocity* (P -values < 0.05) and *Stimulation* (P -values < 0.05), except when the companion was 0.5 cm/s ($P = 0.06$). Post-hoc tests on *Velocity* showed that strokes at 3 cm/s were significantly more pleasant than strokes at 0.5, 1, 10 and 30 cm/s (P -values < 0.05) and post-hoc tests on *Stimulation* showed that brush stimulation was significantly more pleasant than AHM stimulation (P -values < 0.05) (Fig. 1B). Overall, the results showed that strokes at 3 cm/s were unaffected by the judgment of accompanying strokes, regardless of the stimulation. Strokes at 3 cm/s were the most pleasant across conditions, which coincide with the optimal stimulus velocity for CT afferents. Unsurprisingly, the brush was rated as more pleasant than AHM, probably due to CT afferents' activity, but the variations in pleasantness rating with respect to velocity was similar for the two stimulations. There was no difference between the stimulations for stroke speeds up to 0.5 cm/s. This result can be attributed to the lack of CT and A β activity at this velocity compared to higher velocities [1].

Thus, it is possible that velocity serves as an effective cue for the interpretation of tactile sensations, without necessarily relying directly on CT activity. Further investigations will be performed to identify more precisely the impact of velocity and activation of CT afferents in the creation of pleasantness percept.

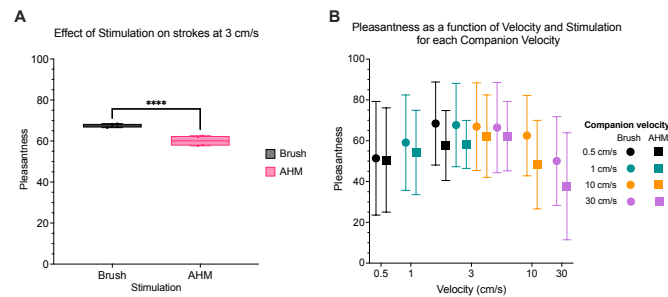


Fig. 1. **A.** Effect of Stimulation on pleasantness rating for strokes at 3 cm/s. Data points represent averaged values across participants. **B.** Pleasantness rating (mean and SD) as a function of velocity and stimulation for each companion velocity. All pairs of comparisons were merged in one graph but were analyzed separately.

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Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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