Degree project

UNIVERSITY OF SKÖVDE

Somatosensory Attenuation:

Differences in the Attenuation of Self-Generated Touch in terms of Intensity, Pleasantness and Ticklishness

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Abstract

The phenomenon of somatosensory attenuation describes the perception that self-generated touch feels weaker than externally generated touch of identical intensity. Previous studies have shown that besides intensity, self-generated touches feel less pleasant and less ticklish than identical externally generated touches. However, previous studies did not systematically assess attenuation across a range of stimuli that can elicit intensity, pleasantness, and ticklishness more efficiently. This thesis aims to replicate these previous observations across a range of tactile stimuli of different intensities and velocities and investigate whether people who attenuate their self-generated touches to a greater extent do so for all aforementioned qualities. Previous studies have shown that participants with lower levels of somatosensory attenuation have more schizotypal personality traits. Twelve volunteers participated in three perceptual tasks where they received touches on their sole generated either by a robot(External) or the participants(Self). Following the strokes, participants had to rate the sensation from 0(*not at all*) to 100(*extremely*). For the intensity task, we manipulated the intensity of the applied forces (1,2,3,4N). For the pleasantness and ticklishness tasks, we manipulated the velocity of the applied strokes (0.3,1,10,30cm/s). After the tasks, participants completed a Schizotypal Personality Questionnaire (SPQ). Significant somatosensory attenuation was observed in all tasks, but for specific, not all, stimuli: forces of 4N in terms of intensity, strokes of 1cm/s in terms of pleasantness, and strokes of 10cm/s and 30cm/s in terms of ticklishness. These results suggest that the ability to suppress the tactile consequences of self-generated touch occurs in all three tactile qualities.

Keywords: *Somatosensory attenuation, efference copy, intensity, pleasantness, ticklishness, schizotypy, SPQ*

Somatosensory Attenuation: Differences in the Attenuation of Self-Generated Touch in terms of Intensity, Pleasantness and Ticklishness

It is essential for both humans and animals to effectively distinguish if the sensory input came from the self or the environment. If not, our brain could not differentiate between a spider crawling up our neck and our fingers scratching the same part of the skin. One strategy that the brain uses to do so is to suppress the self-generated input and therefore amplify the difference from externally generated inputs (Bays et al., 2008; Blakemore et al., 2000a). This perceptual phenomenon is called somatosensory attenuation and occurs in both humans and animals. For example, in humans, a self-generated touch is perceived as less intense than an identical externally generated touch (Bays et al., 2005; Blakemore et al., 1999; Shergill et al., 200).

It has been theorized that the brain attenuates self-generated touch because the brain can predict the self-generated touch compared to an externally generated touch that is not predictable (Bays et al., 2006). Accordingly, when we carry out a voluntary motor action, it is thought that we create a copy of the motor instruction, called efference copy (Sperry, 1950; von Holst & Mittelstaedt, 1971). This efference copy is used to anticipate the voluntary action's consequences by an internal model called the forward model (Kilteni et al., 2020b; Miall et al., 1993; Miall & Wolpert, 1996; Wolpert et al., 1995). By comparing the predicted sensory feedback with the actual sensory feedback, the brain can detect whether the stimulus is self-generated or externally generated, i.e., if the feedback is a match, it is likely that the sensation is self-generated and is then attenuated (see Figure 1). However, if the prediction and the sensory feedback do not match, it is most likely that the sensation was externally generated, and the sensation is not attenuated (Georgieff & Jeannerod, 1998; Jeannerod, 1997).

Sensory attenuation has also been shown for vestibular, visual, and auditory input (Brooks et al., 2015; Horváth, 2015; Klaffehn et al., 2019; Schwarz et al., 2018). In the somatosensory domain, attenuation has been shown in terms of the perceived intensity, pleasantness, and ticklishness of self-generated touch. Multiple studies on the topic have been performed with different methods and designs to investigate this phenomenon.

Somatosensory Attenuation of Intensity

Intensity has nowadays developed into one of the most common ways to test for somatosensory attenuation. Multiple studies on somatosensory attenuation of touch intensity have demonstrated that the perceived intensity of a self-generated touch feels less intense than an externally generated touch that is performed either by an experimenter or a robot,

either on the finger, palm, or arm (Bays et al., 2005; Blakemore et al., 1999; Kilteni et al., 2019; Parthasharathy et al., 2020; Whitford et al., 2017). The two most common tests to assess attenuation in terms of intensity are the force-matching tasks (Shergill et al., 2003) and force discrimination tasks (Bays et al., 2005). Generally, in the force-matching task, the participant receives an externally generated tap on their finger. Afterward, they will have to try to reproduce the tap with the same intensity as the externally generated one, which is commonly measured with a force sensor. When the participants try to recreate the received force, they tend to apply a much higher force than the force that they just received, i.e., they perceived their self-generated touch as less intense than it actually was (Kilteni & Ehrsson, 2017a, 2017b; Kilteni et al., 2019; Shergill et al., 2003; Wolpe et al., 2016).

For the force discrimination task, the participant is asked to differentiate between taps on their index finger and then rate which tap they felt was the strongest. Typically, force discrimination tasks have three conditions, an Active tap condition when the participant actively presses a button, a test tap, where participants receive a tap on their resting index finger, and a comparison tap that is used in design where investigating the perceived difference in force between two taps (Test and Comparison tap). (Bays et al., 2005, 2006; Kilteni & Ehrsson, 2020a; Kilteni et al., 2019). Bays and colleagues tested a movement condition in which participants pressed a button attached to their resting left index finger with their right index finger (active tap). Seven different taps (Test tap) occurred at different time-points between -300 ms before or after the active tap. When participants pressed the force sensor (active tap) simultaneously as the test tap was given, participants perceive the intensity of the test tap as less intense even though the force might be higher or the same as the comparison tap (Bays et al., 2005, 2006; Kilteni & Ehrsson, 2020a; Kilteni et al., 2019).

Somatosensory Attenuation of Pleasantness

Somatosensory attenuation has further been explored by investigating how pleasant a stimulus is experienced. In previous studies, similar results have been demonstrated for pleasantness as for intensity, where self-generated strokes have been perceptually attenuated compared to externally generated strokes. I.e., externally generated strokes were perceived as more pleasant than self-generated strokes (Blakemore et al., 2000b; Whitford et al., 2017). In the experimental procedures by Blakemore et al. (2000b) and Whitford et al. (2017), a piece of soft foam attached to a 70 cm plastic rod was used for the stimulation. The rod was limited to only vertical movements of an amplitude of 1.5 cm. The rod was hidden in a box, and in the self-generated touch condition, the participants rotated the rod at approximately 2 Hz, and in the externally generated touch condition, the experimenter rotated the rod approximately 2 Hz to produce the stimulus on the left palm of the participants. After each trial, the participants

rated how pleasant a given stimulus was on an 11-point Likert scale from 0 (*not at all*) to 10 (*extremely*). Participants perceived their own touch as less pleasant than the externally generated touch.

Somatosensory Attenuation of Ticklishness

Finally, somatosensory attenuation has been demonstrated in multiple studies in terms of ticklishness by showing that when a self-generated stroke is applied on the arm, palm, or the foot sole, the self-generated touch is perceived as less ticklish compared to externally generated touch (Blakemore et al., 2000a; Claxton, 1975; Lemaitre et al., 2016; Weiskrantz et al., 1971; Whitford et al., 2017). Lemaitre and colleagues used a brush mounted to a device that only allowed for horizontal movements in one direction of 6 cm. The participants rated the sensation subjectively, on a 11-point Likert scale from 0 (*not at all*) to 10 (*extremely*). When the participants used the device themselves and performed the stroking on the left forearm, the ticklish sensation was perceived as less ticklish than when the experimenter used the device to perform the movement.

Neural Correlates of Somatosensory Attenuation

Mechanoreceptors in the glabrous skin detect different stimuli such as touch. These mechanoreceptors project the touch to the gracile nuclei in the medulla, consecutively, to the neural posterior lateral thalamus, in succession, projected to the primary somatosensory cortex (Kandel et al., 2000). However, the receptors are not able to detect if the touch is self-generated or externally generated. The aforementioned internal forward model has been proposed to be located in the cerebellum (Shadmehr & Krakauer, 2008; Shadmehr et al., 2010; Therrien & Bastian, 2019; Wolpert et al., 1998). Blakemore et al. (1998) demonstrated reduced activity in the contralateral cerebellum and bilateral secondary somatosensory cortex to the hand that received the touch, while the participants performed a voluntary action in contrast to when they did not perform a voluntary action. Opposing results were found in the study by Shergill et al. (2003), where they showed an increase in activity in the contralateral cerebellum during voluntary action.

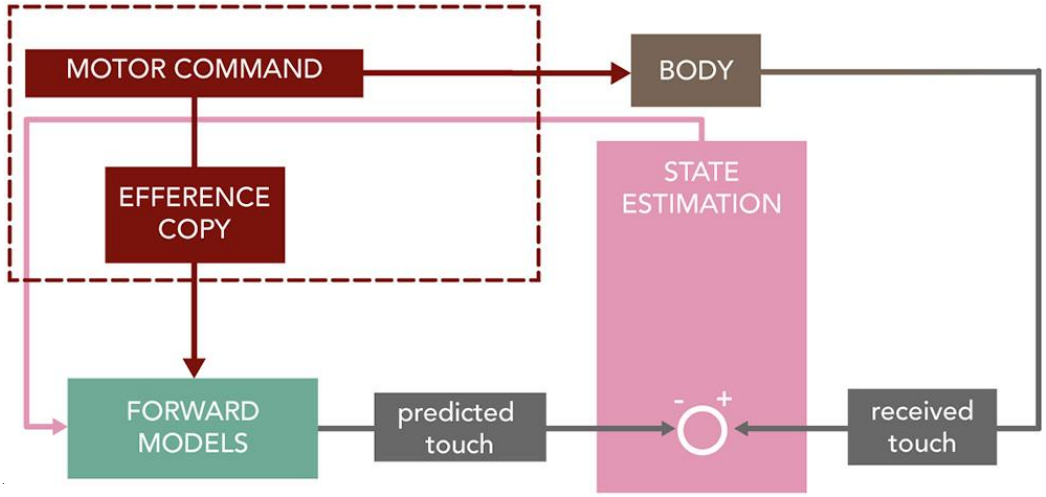
These results combined invite the question of what role the cerebellum has regarding somatosensory attenuation. However, Kilteni and Ehrsson (2020a) demonstrate with psychophysics and functional magnetic resonance imaging (fMRI) that the ipsilateral cerebellum was activated for the passive limb. Furthermore, activity was observed in the bilateral secondary somatosensory areas during self-generated movement. Shergill et al. (2003) used an experimental design that only compared brain activity between a self-

generated condition and an externally generated condition. Since the participants performed a voluntary movement in the self-generated condition, the activity that was observed was seen in the contralateral cerebellum. However, in the studies by Blakemore et al. (1998) and Kilteni and Ehrsson (2020a), another condition was implemented where the participants only moved their arm and hand so later this condition could be subtracted from the self-generated condition, i.e., only the self-generated touch was observed in the fMRI analysis.

Kilteni and Ehrsson (2020a) further showed that when a participant displayed higher somatosensory attenuation, the stronger the functional connectivity between the ipsilateral cerebellum and the bilateral secondary and contralateral primary somatosensory areas, suggesting that there is an interplay between the ipsilateral cerebellum and the bilateral secondary and contralateral primary somatosensory areas where the different parts exchange information.

Figure 1.

A Theorized Model of Somatosensory Attenuation.



Note, during a voluntary movement of the right hand to touch the left foot, a copy of the motor command (efference copy) that is sent to right hand is also sent to the theorized forward model, consequently predicting the position of the right hand and the proprioceptive input. Furthermore, the state of the left foot is predicted. If the anticipated positions of the right hand and the left foot are close, touch is anticipated and therefore the incoming touch is attenuated. Reprinted from "Efference copy is necessary for the attenuation of self-generated touch" by K.Kilteni, 2020, *Iscience, 23*(2), 100843. Copyright [2020] Kilteni and Ehrsson. Reprinted with permission.

Somatosensory Attenuation in Individuals with Schizotypal Personality Traits and Schizophrenia

Alterations in somatosensory attenuation have been previously linked with schizophrenia and schizotypal personality traits (Blakemore et al., 2000b; Shergill et al., 2005; Whitford et al., 2011). Schizophrenia is a clinical diagnosis that includes two or more of the following criteria, delusions, hallucinations, disorganized speech, grossly disorganized or catatonic behavior, and negative symptoms, such as diminished emotional expression (American Psychiatric Association, 2013). In comparison, schizotypy is a set of personality characteristics and experiences throughout the overall population—for example, unusual perceptual experiences, social anxiety, and odd or eccentric behavior. A common way of measuring an individual's schizotypal personality traits is via the Schizotypal Personality Questionnaire (SPQ) (Raine et al., 1994).

It has been proposed that there could be complications regarding the perceived sensation if one had an impaired internal forward model, i.e., it would be unclear if the sensation were externally or self-generated (Blakemore et al., 2002; Williams et al., 2010). Multiple studies have shown that clinically diagnosed patients with schizophrenia showed less somatosensory attenuation than healthy subjects in force-perception tasks (Shergill et al., 2005, 2014; Whitford et al., 2011). Furthermore, previous studies have shown that healthy individuals, in most cases, are not able to perceive their self-generated touch as ticklish (Blakemore et al., 1998). However, Blakemore et al. (2000b) demonstrated that clinically diagnosed schizophrenia patients found their self-generated touches to be more ticklish than healthy controls.

Schizotypal personality traits and their relationship to somatosensory attenuation have been investigated in the healthy population by Blakemore et al. (2000b) and Whitford et al. (2017), demonstrating that participants with higher SPQ scores displayed less somatosensory attenuation for three different perception tasks. In the study by and Whitford et al. (2017), participants either performed a self-generated movement or the experimenter performed the movement on the participants' left palm. After each trial for both the self-generated condition and for the externally generated condition, the participants rated how intense, pleasant, and ticklish the perceived touch felt on a Likert scale ranging from 0 (*not at all*) to 10 (*extremely*). The participants perceived the self-generated touch as less intense, less pleasant, and less ticklish than the externally generated touch in both studies. Furthermore, the participants' that displayed higher somatosensory attenuation had lower SPQ scores.

The Rationale for The Present Study

This study investigates the phenomenon of somatosensory attenuation across intensity, pleasantness, and ticklishness in a within-groups design. In addition, the aim was to replicate the relationship between somatosensory attenuation with schizotypal personality traits in healthy individuals.

In contrast to previous studies by Blakemore et al. (2000b), Lemaitre et al. (2016), and Whitford et al. (2017), where they investigated the three qualities during the same trial and only used one stimulus for intensity and velocity. To my knowledge, no previous studies have investigated the three aspects of somatosensory attenuation with different levels of forces and intensities. To assess somatosensory attenuation systematically across a range of stimuli could show that specific levels of forces and intensities could be more efficient in eliciting intensity, pleasantness and ticklishness sensations. In the current study, I will use multiple intensities and velocities to allow for a more fine-grained investigation of each quality. Furthermore, I will explore the three different perceptual qualities in individual tasks.

In addition, somatosensory attenuation for all three qualities has been investigated in multiple studies on the fingers and palms (Blakemore et al., 2000b; Lemaitre et al., 2016; Whitford et al., 2017); however, only one study by Weiskrantz et al. (1971) has investigated somatosensory attenuation on the sole but only in regards to ticklishness. Furthermore, since Whitford and colleagues received low scores for the externally generated condition (M=2.63, range 0-10). One reason for these low scores might be the area that was stimulated, i.e., the palm of the hand. In the present study the stimulus was applied on the sole of the foot for all three qualities and not on the arm or the palm since the sole has also been shown to be more ticklish than the arm (Harris, 1999).

Previous studies by Whitford et al. (2017) and Lemaitre et al. (2016) investigated whether participants' who displayed strong attenuation in one perceptual quality also showed strong attenuation in the other two. In the present study, I investigated this phenomenon as well, furthermore, if participants with lower attenuation in each quality present a higher SPQ score.

Concerning somatosensory attenuation, our first (1) hypothesis is that participants will perceive their self-generated touch on their foot sole as less intense, less pleasant, and less ticklish than an externally generated touch, replicating previous studies (Blakemore et al., 2000b; Lemaitre et al., 2016; Whitford et al., 2017). Furthermore, our second (2) hypothesis is that the participants with strong attenuation in one quality (intensity, pleasantness, or ticklishness) will also show strong attenuation in the other two. Finally, our third (3) hypothesis is based on the study by Whitford et al. (2017). We expected participants with high

schizotypal personality traits to perceive the intensity and ticklishness of their self-generated touch as stronger than those with low schizotypal personality traits. We also expected the same pattern for the perceived pleasantness, although a previous study failed to find such association (Whitford et al., 2017).

The results of the present experiments could yield a better understanding of how people perceive touches in general since the mechanisms for voluntary actions are not fully understood. Furthermore, to gain new fundamental knowledge of how voluntary actions relate to neurological and psychiatric disorders, like schizophrenia. If participants with lower somatosensory attenuation demonstrate a higher SPQ score, a task that controls for somatosensory attenuation could be used as a screening tool for predisposition to schizophrenia during adolescence.

Methods

Participants

The study was designed to include thirty-six participants (36). The sample size was based on previous studies and for counterbalancing the tasks and conditions. Nevertheless, due to COVID-19 restrictions, only twelve participants (11 males), 11 right-handed, and one ambidextrous, aged 22-34 (M=29.34, SD=3.96), participated in the experiment. The participants were recruited through social media channels (Facebook groups) and dedicated web pages and received compensation for participation by choosing 225 SEK (taxable) or two cinema tickets.

Participants had normal vision or corrected to normal with lenses or glasses, no current or history of psychological or neurological conditions. Moreover, they should not take any psychoactive drugs or medication. Furthermore, they should understand English or Swedish and had not participated in any previous somatosensory attenuation experiments beforehand. Handedness was assessed using the Edinburgh Handedness Inventory (Oldfield, 1971), where the handedness score was ranging from 20 to 100 (M=90, SD=24.86). The Swedish Ethical Review Authority approved the study (Record number# 2020-03186, amendment #2020-05457).

Design

This study's research design was within-groups, with two different parts, the first was part regarding three perceptual tasks quantifying somatosensory attenuation, and the second part was a personality questionnaire (SPQ). The three tasks investigated somatosensory attenuation for intensity (Force-perception task), pleasantness (Pleasantness-perception

task), and ticklishness (Ticklishness-perception task). Each of the three tasks had two conditions; in one condition, the participants had to perform a movement themselves to generate the touch (Self-generated touch condition), and in the other condition, a robot (Touch Haptic Devices, 3D systems, https://www. 3dsystems.com/haptics-devices/touch) applied the touch (Externally generated touch condition). The order of the tasks and conditions was counterbalanced. The applied stimulus for the force-perception task was 1,2,3, and 4N of force, and for the pleasantness-perception and ticklishness-perception task, the velocities of 0.3,1,10, and 30cm/s. The order of the different forces/velocities was pseudo-randomized. Furthermore, the first stimulus in each task was counterbalanced due to possible order effects. In total, there were six blocks: self-generated force, pleasantness, and ticklishness task, and externally generated force, pleasantness, and ticklishness task. Each block involved 16 trials. The personality questionnaire was always given after the perceptual tasks.

Experimental Procedure

Upon arrival, all participants had to provide written informed consent. Then, they removed their shoe and sock and placed their left foot on a support ledge where they rested their foot so that the metatarsals were in line with the hole in the box where the stimulus was received. There were different templates (holes) for each of the tasks (See Appendix A for a picture of setup and the different holes for each task); the metatarsal was preferred compared to the arc because it is a flat area, and thus, it allows us to apply the touches similarly across all participants. The robot was placed inside the box and was lined up to the hole where the stimulus was given. Participants could not see the robot but were also asked to wear a sleeping mask during all attenuation trials for each task. Furthermore, the participants were wearing headphones throughout the experiment where white noise was administered so the participants could not hear each trial's initiation or the sound from the robot during all perceptual tasks.

Force Perception Task

In the externally generated touch condition, the participant received a poke on their sole (metatarsals) through the hole in the box at four different intensities (1,2,3 and 4N) applied by a cylindrical 3D printed rod with a diameter of 1 cm attached to the robot (See Appendix B for a picture of the rod). The four different force levels were chosen to match the number of levels in the pleasantness-perception task and ticklishness-perception task and to have a distinct difference between each level of the forces.

In the self-generated touch condition, the participants themselves performed the poking with a 3D printed object with the same measurements as the one for the externally generated touch condition, but the rod was not attached to the robot. To enable participants to apply the different force levels, different capsules were attached to the end of the 3D rod depending on the force level. Inside the capsule, a spring was attached that allowed the participants to press the 3D printed object at 1, 2, 3, and 4N, respectively. Moreover, underneath the spring, a force sensor (FSG15N1A, Honeywell Inc; diameter, 5 mm; minimum resolution, 0.01N; response-time, 1ms; measurement-range, 0–15N) was attached to control and record the forces. If the participant did not perform the poke at the correct intensity, they were told to redo the trial.

Pleasantness Perception Task

In the externally generated touch condition, the participant received strokes of 4 cm on their sole (along the metatarsals) through the hole in the box at an intensity of approximately 0.4N and at four different velocities (0.3,1,10 and 30cm/s), based on the study by Ackerley et al. (2014). Previous studies demonstrated that stroked at 1cm/s and 10cm/s were rated as the most pleasant strokes compared to 0.3cm/s and 30cm/s (Ackerley et al., 2014; Gentsch et al., 2015; Löken et al., 2009, 2011). The strokes were performed with a makeup brush (Avalea–Multi-tasking) attached to the robot (See Appendix B for a picture of the brush).

In the self-generated touch condition, the participants moved the robot themselves by grabbing a pen-shaped part of the robot arm. By grapping onto to robot the experimenter was able to both monitor and record the movements of the participants even though the participants were not in direct contact with their skin, since handheld tools have also been shown to attenuate self-touch (Kilteni & Ehrsson, 2017a). The robot arm was locked in horizontal movements, and a piece of plastic was attached to the front of the brush, preventing the movement along the depth axis and consequently preventing the participant from applying more force toward their sole. The plastic piece was attached so the participants would add the same amount of force as in the externally generated touch condition of 0.4N.

The participant was taught how to move the stylus at different velocities without knowing the actual velocity by receiving instructions from the researcher. The monitoring and recordings of the velocities were done via MATLAB R2021a (The Math Works, Inc., Natick, 9 Massachusetts, United States.). If the participant did not perform the stroke at the correct velocity, they were told to redo the trial.

Ticklishness Perception Task

In the externally generated touch condition, the participant received stokes of 4 cm on their sole metatarsals through the hole in the box at an intensity of approximately 1.5N since previous studies have shown that a stronger force yields a more ticklish sensation than a weaker one (Harris, 1999). Furthermore, four different velocities were applied (0.3,1,10, and 30cm/s), the same velocities that were selected for the pleasantness perception task. The stimulus was applied with a pointy plastic edge attached to the robot (See Appendix B for a picture of the plastic edge). In the self-generated condition, the same procedure as in the pleasantness perception task was applied but with the plastic edge.

The Rating Scale for Perception Tasks

In both the externally generated and the self-generated conditions and after each trial, the participants had to rate how intense, pleasant, and ticklish they felt the stimulus. The ratings were performed on a visual analog scale (VAS), where the participants rated the stimulus perception from 0 (*not at all*) to 100 (*extremely*). The participants did not know the scale's value (0 - 100) except for the" *not at all*" and "*extremely*" limits (see Appendix C for a picture of the VAS). The VAS was conducted in English on a laptop that was placed in front of the participant.

Schizotypal Personality Questionnaire

After completing the perceptual tasks, the participants filled in the Schizotypal Personality Questionnaire (SPQ) that was conducted in English (Raine et al., 1994). The SPQ is a 74-item, yes or no questionnaire that measures schizotypy in healthy individuals with a minimum score of 0 and the maximum score of 74. The SPQ has high internal consistency and high correlations among the SPQ items. Cronbach's alpha for the SPQ is 0.926. The questionnaire is divided into three subcategories called Raine's three-factor model (Cognitive-Perceptual, Interpersonal and Disorganized) (Raine et al., 1994).

Data Analysis

The normality of the participants' ratings, the attenuation index, the SPQ full score data were tested using the (Shapiro-Wilk test Shapiro & Wilk, 1965). All data were analyzed using R (R version 4.1.0) (Core Team 2021), MATLAB R2021a (The Math Works, Inc., Natick, 9 Massachusetts, United States.), and JASP (JASP and JASP Team, 2020).

For each of the three tasks in the current experiment, the rating scores were averaged across trials for each participant. We analyzed the participants' ratings in a repeated-measures analysis of variance (ANOVA) with two within-subjects' factors: The *Condition* (External, Self), and the *Level* (four different forces in N, and four different velocities in cm/s). Following, we performed planned comparisons using a paired t-test and post hoc test using Holm correction to adjust the p-value.

We then calculated the attenuation index of each participant by taking each participant's mean score in the self-generated touch condition and subtracting it from the mean score from the externally generated condition for each *Level*. For example, the attenuation index for the intensity of 4N is the intensity rating for the 4N when the externally generated, minus the intensity rating for the 4N when self-generated. To investigate if there was a difference in attenuation indexes between the tasks, repeated-measures analysis of variance (ANOVA) was conducted between the attenuation indices of the different tasks. Following, we performed planned comparisons using a paired t-test.

Moreover, to investigate whether the attenuation indexes correlate with each other between the different tasks, a correlational analysis was performed either by Pearson correlation or Spearman correlation, depending on the normality of the data.

Finally, to examine the relationship between the participants' level of attenuation index and their SPQ full scores, a correlation analysis was performed either by Pearson correlation or Spearman correlation, depending on the normality of the data.

Results

All 12 participants completed each of the 16 trials per condition and task. Table 1 shows all the participants' average scores on each of the six blocks in the perceptual experiment. In the current study the scores on the full SPQ ranged from 6 to 42 (M=19.75, SD=11.02). See Figure 2 for a comparison between all participants' data for both conditions and for each task and see Appendix D for descriptive plots of each participant data for both conditions and for each task.

Table 1.

All participants Mean, Standard Error, Standard Deviations and Range of Scores on all Perceptual Tasks.

	EF-Score	SF-Score	EP-Score	SP-Score	ET-Score	ST-Score
Mean	22.125	18.917	31.391	27.667	26.203	17.568
Std. Error of Mean	1.489	1.250	1.687	1.623	1.558	1.176
Std. Deviation	20.627	17.314	23.372	22.487	21.585	16.302
Minimum	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	80.000	70.000	74.000	79.000	71.000	60.000

Note. Mean, Standard Error, Standard Deviations and Rage of scores on each of the 6 blocks. Score of Externally generated Intensity (EF-Score), Self-generated Intensity (SF-Score), Externally generated Pleasantness (EP-score), Self-generated Pleasantness (SP-Score), Externally generated Ticklishness (ET-Score), and Self-generated Ticklishness (ST-Score).

Force Perception Task

A repeated-measures ANOVA revealed a significant main effect of Force level ($F(3, 33)=31.741$, $p<.001$), a significant interaction of the Force level * Condition ($F(3, 33)=4.684$, $p=.008$) and no significant main effect of the Condition ($F(2, 58)=1.670$, $p=.223$). The pairwise comparisons revealed a significant difference between all pairs for the different force levels. That is participants discriminated the different levels of the forces applied on their foot sole. Specifically, post hoc tests indicated that 4N were perceived significantly stronger than 3N ($p<.001$), 3N were perceived significantly stronger than 2N ($p<.001$), and 2N were perceived significantly stronger than 1N ($p=.050$), see Table 2 for descriptive statistics of the intensity task. Investigating the interaction effect, significant difference was observed only between the external and self-condition for the highest force, 4N ($t(11)=2.466$, $p=.031$). No other significant differences were seen between the external and self-condition for the forces of 1N ($t(11)=24.500$, $p=.271$), 2N ($t(11)=48.500$, $p=.480$). A strong trend was observed for 3N showing that self-generated 3N feel weaker than externally generated 3N ($t(11)=62.000$, $p=.077$) (See Figure 2A for descriptive plot).

Table 2.

Descriptive Data for all Participants on the Force-perception Task

Force Level	Condition	Mean	SD	N
1N	External	7.146	8.064	12
	Self	7.146	5.652	12
2N	External	14.521	12.504	12
	Self	12.583	9.370	12
3N	External	28.188	19.750	12
	Self	24.313	17.649	12
4N	External	38.646	22.025	12
	Self	31.625	19.429	12

Note. Mean and Standard Deviation for all participants' scores on the force-perception task for all force levels (1,2,3, and 4N) and per condition (external and self).

Pleasantness Perception Task

A repeated-measures ANOVA revealed a significant interaction between Condition and Velocity level ($F(3, 33)=3.036$, $p<.043$), but no significant main effects for either the Velocity level ($F(3, 33)=2.003$, $p=.133$), or Condition ($F(1, 11)=.560$, $p=.470$). When investigating the interaction, a significant difference between the external and self-generated condition was observer only for the 1cm/s velocity ($t(11)=67.00$, $p=.031$). No significant difference was seen between the external and self-generated condition for the velocities of 0.3cm/s ($t(11)=40.00$, $p=.969$), 10cm/s ($t(11)=1.540$, $p=.152$), and for 30cm/s ($t(11)=.777$, $p=.453$) (See Figure 2B for descriptive plot).

Since previous studies have demonstrated that a velocity between 1cm/s and 10cm/s was perceived as the most pleasant stroking speed (Ackerley et al., 2014; Gentsch et al., 2015; Löken et al., 2009, 2011), we wanted to investigate further if similar results were displayed in the present experiment. We looked at the perceived pleasantness for the different velocities in the externally generated condition only. Replicating these previous effects, the velocity of 1cm/s ($M=36.146$) and 10cm/s ($M=34.958$) were perceived as the most pleasant velocities, whereas the velocities of 0.3cm ($M=24.521$) and 30cm/s ($M=29.896$) was perceived as less pleasant, as shown in Figure 2B, see Table 3 for descriptive statistics of the pleasantness task.

Table 3.

Descriptive Data for all Participants on the Pleasantness-perception Task

Velocity Levels	Condition	Mean	SD	N
0.3	External	24.521	23.034	12
	Self	26.854	25.871	12
1	External	36.146	23.888	12
	Self	29.771	21.068	12
10	External	34.958	22.144	12
	Self	28.271	20.132	12
30	External	29.896	19.896	12
	Self	25.771	23.974	12

Note. Mean and Standard Deviation for all participants' scores on the pleasantness-perception task for all velocity levels (0.3,1,10, and 30cm/s) and per condition (external and self).

Ticklishness Perception Task

A repeated-measures ANOVA revealed a significant main effect of the different Velocity level ($F(3, 33)=8.356$, $p<.001$), a significant interaction of the Velocity level * Condition ($F(3, 33)=8.927$, $p<.001$) and no significant main effect of Condition but a statistical trend ($F(1, 11)=4.006$, $p=.071$). The pairwise comparisons revealed a significant difference between all pairs for the different Velocity levels. Post hoc tests showed that there was a significant difference between the velocities of 1cm/s and 10cm/s ($p=.016$), but no significant differences between the velocities of 0.3cm/s and 1cm/s ($p=0.420$), or 10cm/s and 30cm/s ($p=.692$). When investigating the interaction effect, a significant difference was detected between the external condition and self- generated condition for the velocities of 10cm/s ($t(11)=2.651$, $p=.023$), and 30cm/s ($t(11)=3.805$, $p=.003$), but no significant differences between the external and self-generated condition for the velocities of 0.3cm/s ($t(11)=0.499$, $p=.627$), and for 1cm/s ($t(11)=0.539$, $p=.601$) (See Figure 2C for descriptive plot).

Similar to the pleasantness task, we investigated further what velocity was perceived as the most ticklish. The most ticklish velocities for the externally generated condition were 10cm/s ($M=35.000$) and 30cm/s ($M=32.646$). While the velocities of 0.3cm/s ($M=16.667$) and 1cm/s ($M=20.500$) were not perceived as ticklish as shown in Figure 2C, see Table 4 for descriptive statistics of the ticklishness task.

Table 4.

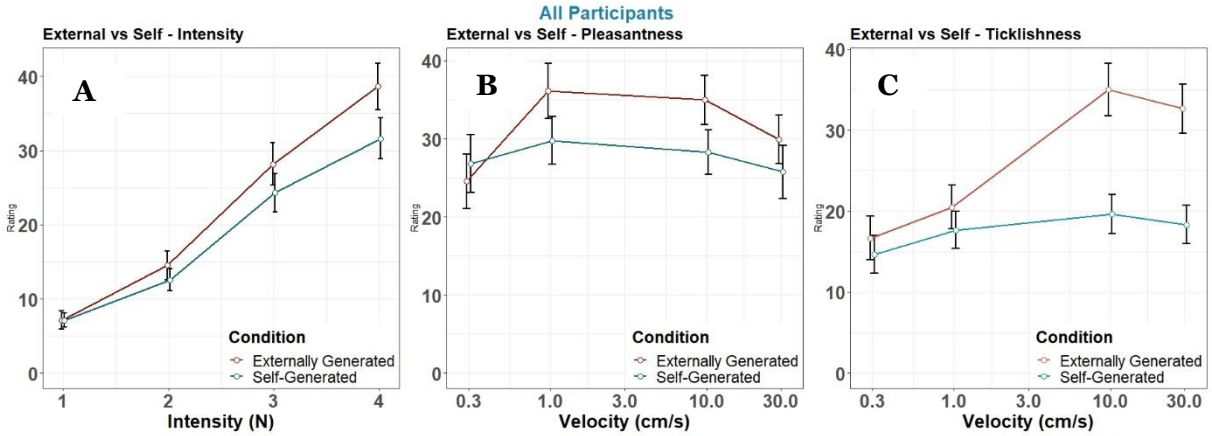
Descriptive Data for all Participants on the Ticklishness-perception Task

Velocity Levels	Condition	Mean	SD	N
0.3	External	16.667	17.782	12
	Self	14.667	16.414	12
1	External	20.500	18.435	12
	Self	17.646	15.826	12
10	External	35.000	21.924	12
	Self	19.646	16.950	12
30	External	32.646	20.559	12
	Self	18.313	16.328	12

Note. Mean and Standard Deviation for all participants' scores on the ticklishness-perception task for all velocity levels (0.3,1,10, and 30cm/s) and per condition (external and self).

Figure 2.

Intensity, Pleasantness, and Ticklishness, Mean Scores and Standard Error of Mean for all Participants for each Level.



Note. Comparison between condition (external vs self) for each of the three attenuation tasks, force-perception task (A), pleasantness perception task (B), and ticklishness perception task. The dots represent the mean for each level for all participants where the bars display the standard error of the mean.

Relationship Between Somatosensory Attenuation and each Task

To assess whether the participants who demonstrated somatosensory attenuation in one task also showed somatosensory attenuation in the other two tasks, we looked at the difference between the participants' attenuation index in one task compared to the other two tasks; a repeated-measures ANOVA was conducted. No significant results were demonstrated between the three tasks ($F(2,22)=1.476$, $p<.250$), indicating that the attenuation index in one task was comparable to the other two tasks.

Next, we looked at the difference of the attenuation index for those stimuli that elicited the highest somatosensory attenuation (See Table 5). For all participants' individual attenuation indexes, see Appendix E. We performed a repeated-measures ANOVA that demonstrated a significant main effect of tasks ($F(2,22)=3.458$, $p<.049$). In contrast to the aforementioned results for all participants' attenuation indexes where there was no major difference between the attenuation indexes for all three tasks, these results indicate a difference between the attenuation index for all three tasks and participants attenuated more in one task than on another. To investigate where this difference was, a paired sample t-test was performed. A significant difference was shown between the 4N Intensity condition and 10 cm/s and 30cm/s ticklishness condition ($t(11)=6.000$, $p=.026$). No significant difference was shown between 4N Intensity condition and 1cm/s pleasantness condition ($t(11)=0.198$, $p=.847$), and between 10cm/s and 30cm/s ticklishness condition and 1cm/s pleasantness condition ($t(11)=1.957$, $p=.076$). These results show that when considering the most efficient stimuli, participants attenuated more in the ticklishness task than in the intensity and pleasantness tasks.

Table 5.

All Participants Mean, Standard Deviations, and Ranges across Conditions of Attenuation Indexes for all Perceptual Tasks.

Rating	Condition	Mean (SD)	Range
Intensity	External	22.125 (20.627)	0 to 80
	Self	18.917 (17.314)	0 to 70
	All levels attenuation index (external minus self)	3.205 (8.600)	-13 to 19.5
	4N - attenuation index (external minus self)	7.021 (9.861)	-16.5 to 22.75
Pleasantness	External	31.391 (23.372)	0 to 74
	Self	27.667 (22.487)	0 to 79
	All levels attenuation index (external minus self)	3.724 (17.205)	-39.6 to 39.5
	1cm/s - attenuation index (external minus self)	6.375 (18.669)	-35.25 to 47.5
Ticklishness	External	26.203 (21.585)	0 to 71
	Self	17.568 (16.392)	0 to 60
	All levels attenuation index (external minus self)	8.623 (14.929)	-27.2 to 37.6
	10 cm/s and 30cm/s - attenuation index (external minus self)	14.844 (15.813)	-18.125 to 43.5

Note. The table displays all participants Mean, Standard Deviation and ranges for each condition (external and self) for All levels of attenuation index (All levels attenuation index) for all three tasks and for the force and velocity levels that elicited the strongest attenuation (4N - attenuation index, 1cm/s - attenuation index, and 10 cm/s and 30cm/s - attenuation index (external minus self).

Correlation Between the Attenuation Indexes for each Task.

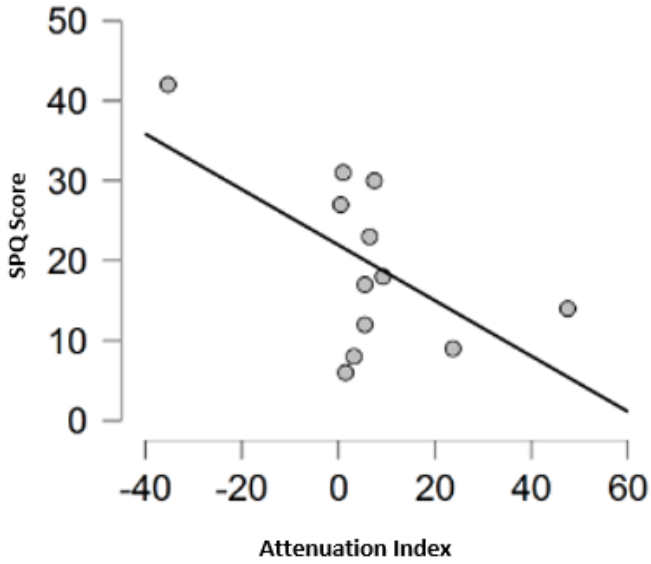
A correlation analysis was conducted to investigate whether the attenuation indexes correlate with each other in the three tasks. First, we looked at the total attenuation index for all tasks. The participants' attenuation index for intensity was significantly positively correlated with the attenuation index for ticklishness ($r(10)=.600$, $p=.039$). However, no significant correlation was obtained for the attenuation index for intensity and pleasantness ($r_s(10)=.552$, $p=.067$), or for the attenuation index for pleasantness and ticklishness ($r_s(10)=.510$, $p=.094$). In addition to the correlation of all levels of attenuation indexes, we also looked at the relationship in somatosensory attenuation between the three different tasks for the levels that were significant. We performed another correlation analysis where the intensity level of 4N was significantly positively correlated with the pleasantness level of 1cm/s ($r(10)=.864$, $p<.001$), and the intensity level of 4N was also significantly positively correlated with the ticklishness level of 10 and 30cm/s ($r_s(10)=.789$, $p=.002$). No correlation was observed for between the pleasantness level of 1cm/s and ticklishness level of 10 and 30cm/s ($r_s(10)=.466$, $p=.127$).

Relationship Between Attenuation Index and SPQ Scores

We then assessed whether participants with lower attenuation index displayed higher schizotypal personality traits, i.e., higher SPQ scores. A correlation analysis was performed between all levels of attenuation index and SPQ scores. No significant correlation was observed between any task and SPQ scores. However, we also performed a correlation analysis between SPQ scores and the three different tasks for the significant attenuation levels. A significant negative correlation was seen for the pleasantness level of 1cm/s and SPQ scores ($r(10)=-.589$, $p=.022$) suggesting that individuals with higher schizotypy attenuate less the pleasantness of their self-generated touches (See Figure 3). However, when excluding one participant with pleasantness attenuation index scores of >= 2 standard deviations from the group mean, no significant correlation was observed ($r(10)=-.259$, $p=.442$). While there were no significant correlations for either the intensity level of 4N and SPQ scores ($r(10)=-.459$, $p=.067$), and for the ticklishness level of 10 and 30cm/s and SPQ scores ($r_s(10)=-.119$, $p=.358$).

Figure 3.

Correlation Between the Attenuation Index for the Pleasantness level of 1cm/s and SPQ Scores.



Discussion

Concerning somatosensory attenuation, our first (1) hypothesis is that people will perceive their self-generated touch on their foot sole as less intense, less pleasant, and less ticklish than an externally generated touch, replicating previous studies (Blakemore et al., 2000b; Lemaitre et al., 2016; Whitford et al., 2017). Furthermore, our second (2) hypothesis is that the participants with strong attenuation in one quality (intensity, pleasantness, or ticklishness) will also show strong attenuation in the other two. Finally, our third (3) hypothesis is based on the study by Whitford et al. (2017), where participants with higher schizotypal personality traits will perceive their self-generated touch for intensity and ticklishness qualities as stronger than those with low schizotypal personality traits since Whitford et al. (2017) did not find any significant results for the quality of pleasantness.

Concerning the first (1) hypothesis, we found that participants gave lower scores for their self-generated touches than externally generated touches in all three tasks. Our results are in line with those of Blakemore et al. (1999, 2000b) and Whitford et al. (2017), showing that a self-generated tactile stimulus is rated as less intense, pleasant, and ticklish than an externally generated stimulus. However, we observed that the self-generated tactile stimulus was not attenuated similarly across the different forces and velocities. Specifically, the perceived intensity was attenuated only for the forces of 4N, the perceived pleasantness was

attenuated only for the velocity level of 1cm/s, and the perceived ticklishness was attenuated only for the velocity levels of 10 and 30cm/s. Below we discuss these effects in detail.

In the *force perception task,* we observed a significant difference in attenuation between the externally generated and the self-generated condition for the strongest force (4N). However, we observed a significant difference in the perceived intensity between all levels of intensity except between 1N and 2N, i.e., the participants were able to discriminate between all forces except for 1N and 2N. This finding is not in line with previous studies on a force-matching task where participants could differentiate weaker forces than an interval of 1N (Kilteni & Ehrsson, 2017a, 2017b; Kilteni et al., 2019; Wolpe et al., 2016). The aforementioned studies applied the different forces on participants' fingertips. This area has been shown to be particularly sensitive to touch (Weinstein, 1968), and the fingertip is where humans have the most Merkel receptors (Johansson & Vallbo, 1979; Vallbo & Johansson, 1984). Since the density of the myelinated afferent is different between body parts, and the metatarsal on the sole has fewer receptors than the fingers, this might be the reason why some participants were not able to discriminate between the low intensities of 1N and 2N.

In the *pleasantness perception task,* we only observed a significant difference in attenuation between the externally generated and self-generated velocity level of 1cm/s. In line with previous studies by Ackerley et al. (2014, Gentsch et al. (2015), and Löken et al. (2009, 2011), regarding what velocity was experienced as the most pleasant ones, we found that the levels of 1cm/ and 10cm/s were perceived as the most pleasant in the externally generated condition. However, we only observed significant attenuation for the velocity level of 1cm/s and not for 10cm/s. We speculate that with a larger sample size, we will detect a significant attenuation for the velocity level of 10cm/s as well.

In the *ticklishness perception task,* we observed a significant difference in attenuation between the externally generated and self-generated velocity levels of 10cm/s and 30cm/s. The externally generated condition results demonstrate that the levels of 10cm/s (M=35.000) and 30cm/s (M=32.646) were perceived as the most ticklish levels, and these were also the levels where the participants demonstrated the highest attenuation. To observe attenuation, we need a positive score in the external condition; this might be why we did not observe attenuation for the slower velocities, i.e., they were not perceived as ticklish at all.

Concerning the second hypothesis (2), we looked at how participants' attenuation index differs between each task for all stimuli levels and for the levels of the most efficient stimuli (i.e., where significant attenuation was found). Findings from all stimuli levels showed no significant difference between the three tasks, suggesting that the attenuation index in one task is comparable to the other two tasks. However, for the

attenuation index for the intensity level of 4N, pleasantness velocity level of 1cm/s, and for ticklishness velocity levels 10cm/s and 30cm/s, a significant result was found where the difference was only observed between intensity and ticklishness. When looking closer at these results, we can interpret them as the participants' showing higher attenuation in the ticklishness compared to the intensity task. Furthermore, we speculate that the trend between pleasantness and ticklishness (p=.076) might be significant in a larger sample size.

These findings, together with the mean of each significant attenuation (See Table 5) level, display that participants exhibit stronger somatosensory attenuation in the ticklishness task compared to the intensity and pleasantness tasks for the levels where the attenuation was highest. A possible argument why we observe these results may be that the sole is the most ticklish area of the human body, as Harris (1999) has shown. Thus, we observe a higher attenuation index for the ticklishness task. However, no previous studies regarding pleasantness or intensity have been performed on the sole to our knowledge. However, Blakemore et al. (1999) reported a higher attenuation for the ticklish sensation than for pleasantness or intensity. On the contrary, Whitford et al. (2017) demonstrated that the attenuation index for intensity was the highest between all three tasks when performing the different tasks. In the study by Whitford et al. (2017), the stimulus was performed at only one level of velocity and one level of force and applied to the participant's palm. Another reason why we might see stronger attenuation for the ticklishness might be because you cannot perceive your own touch as ticklish for the majority of the population. However, you can apply pressure or pleasure yourself.

A further analysis based on the finding of the differences between attenuation indexes was performed to investigate whether the attenuation indexes between tasks correlate with each other. We saw a significant positive correlation between the intensity task and ticklishness task for all levels of attenuation index. This result demonstrates that participants who attenuated in the intensity task also attenuated in the ticklishness task, but not for the pleasantness task. The fact that the attenuation index for pleasantness (M=3.274, SD=8.6) and attenuation index for intensity (M=3.205, SD=17.205), or ticklishness (M=8.623, SD=14.929) did not correlate could depend on the small sample size of this thesis (n=12). However, we observed a significant correlation when looking at the attenuation index for the significant attenuation levels of intensity 4N, pleasantness 10cm/s, and ticklishness 10 and 30cm/s. We observed a positive correlation between all significant attenuation levels except between pleasantness 10cm/s and ticklishness velocity levels of 10 and 30cm/s.

Regarding the third (3) hypothesis, no significant correlations were found between the attenuation index of each of the three tasks and SPQ scores. However, a trend was observed between the pleasantness-perception task and SPQ score (p=.052), and with a

larger sample size, this might yield a significant correlation. Furthermore, we saw a negative correlation between pleasantness level of 10cm/s and SPQ scores (See Figure 3), while no significant correlation was seen between the other two significant attenuation levels and SPQ scores. However, we saw no significant correlation when removing the outlier from the correlation analysis (p=.442). Based on previous studies by Whitford et al. (2017) and Lemaitre et al. (2016), we expected a negative correlation between intensity and ticklishness tasks and SPQ scores. In contrast, we saw no correlation for the respective task either for all levels and for the significant attenuation levels. In contrast, we saw a negative correlation between the 1cm/s pleasantness level and SPQ scores. This result may be based again on a few specific participants since the sample size (n=12) for the current thesis was small; see appendix E for individual attenuation index data.

As discussed previously in this thesis, the ability to anticipate the sensory consequences of voluntary action is made possible by the internal forward model (Figure 1). Concerning the present thesis, when participants are performing a movement in the self-generated condition, the internal forward model predicts the input on the participants left sole. Simultaneously these predictions are matched with the touch received on the sole and attenuate the self-generated action. Since previous studies by Blakemore et al. (1998) and Kilteni and Ehrsson (2020a), demonstrated reduced activity in the cerebellum for the passive limb, we expected similar activity for the present thesis when receiving the touch on the left sole, specifically the ipsilateral cerebellum since the cerebellum is mainly ipsilateral compared to the cerebral cortex (Grodd et al., 2001; Manni & Petrosini, 2004). Furthermore, since participants perform a self-generated movement, we expect to see reduced activity in the bilateral secondary somatosensory areas. We further expect to see more functional connectivity between the ipsilateral cerebellum and the bilateral secondary and contralateral primary somatosensory areas in the ticklishness-perception task compared to the other two tasks since a stronger attenuation was observed in the ticklishness-perception task.

This leads to the next step for future research on the topic. The current study is a behavior experiment; the next step would be to add neuroimaging to the same experimental design to confirm the aforementioned assumptions. Further research in the somatosensory attenuation domain should add more levels, i.e., more velocities or forces to get a more detailed view of attenuation of touch. Additionally, it would be interesting to test other body areas to assess whether they follow the same attenuation pattern since some body parts are more ticklish, and others might be more receptive to either intense or pleasant touch.

There are limitations concerning this thesis. First, we tested a small sample size(n=12) due to COVID-19 restrictions, while a larger sample size could yield a more representative result even though significant results were already shown in the present thesis.

This is crucial since there are many individual differences, e.g., some people might be more ticklish than others. Another limitation that also relies upon sample size is that the current sample has low SPQ scores. To control for correlation between attenuation and SPQ, we need a more representative sample of the whole SPQ range.

The current study was approved by the Swedish Ethical Review Authority. However, there were still some ethical aspects of the experiment. The SPQ that was used for the experiment was not used for diagnostics of the participants, and they had no knowledge that the questionnaire was about schizotypy, only as a personality questionnaire. Furthermore, the SPQ scores were stored in separate files from the consent, and no identification except participant number was shown on the SPQ in respect of privacy.

As mentioned briefly in the introduction, the result from the current study yields a better understanding of the relationship between schizotypy and somatosensory attenuation. To conduct this kind of experiment is very cheap, and you do not require any medical intervention. Therefore, to use a somatosensory attenuation task as a screening tool for people in their adolescents might indicate if these individuals are prone to schizophrenia. A similar paradigm is seen on the effect of aging (Wolpe et al., 2016). Wolpe and colleagues observed that the older you are, the more you attenuate. Therefore, a somatosensory attenuation task could be used to investigate how these predictive mechanisms decline with aging.

Conclusion

By investigating how people perceive self-generated touches compared to externally generated touches in different tactile qualities, this thesis replicates and extends findings from previous studies by demonstrating that people do attenuate their self-generated touches in intensity, pleasantness, and ticklishness. Attenuation was not observed for all levels of velocities and forces. For ticklishness and pleasantness, the velocities that demonstrated attenuation were the ones that elicited the strongest sensation in the externally generated condition. Therefore, to observe attenuation, the need for positive scores in the external condition so that the self gets attenuated. If a touch is not ticklish or pleasant, it will not get attenuated.

Furthermore, there was a stronger attenuation for the ticklishness task than for the pleasantness and intensity of self-generated touches. This finding was probably due to the area (foot sole) stimulated in the current experiment and the fact that we cannot perceive our own touch as ticklish.

Moreover, only a significant negative correlation was seen for one of the velocity levels in the pleasantness task and SPQ scores. However, a larger sample size is needed to determine the relationship between somatosensory attenuation for different aspects of touch and schizotypy.

Ultimately, it is clear that somatosensory attenuation occurs in different aspects of touch and that the amount of somatosensory attenuation is based on the stimulus that elicits a stronger sensation of that specific aspect of touch. Furthermore, the specific part of the body seems to be decisive on how distinct the attenuation is, based on the aspect of touch.

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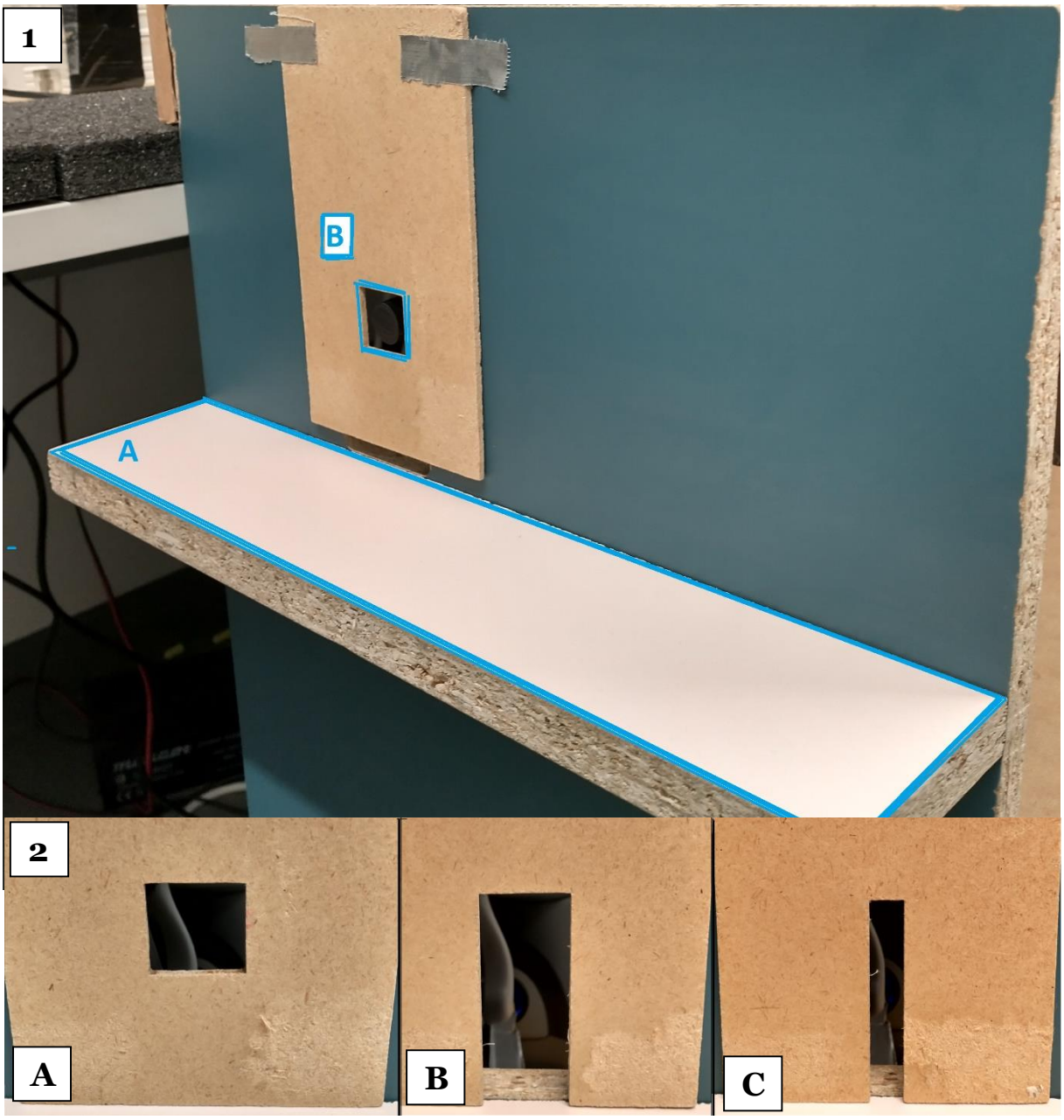
Appendix A

Picture of experimental setup

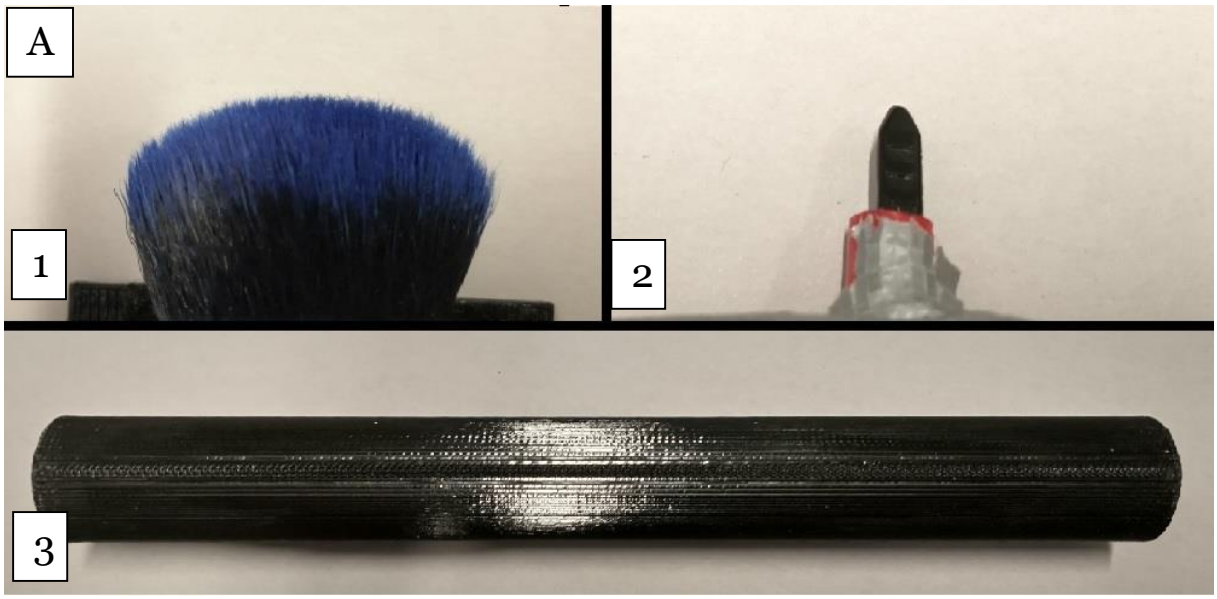
This appendix consists of two pictures of the experimental setup where (1) shows the box and the ledge and (2) shows the templates (holes) for each task. In the first picture (1), (A) displays the ledge that participants' rest their foot on during the experiment. (B) is an example of the hole in the box that is used for the force-perception task. In the second picture (2), (A) displays the template for the force-perception task, (B) displays the template for the pleasantness-perception task, and (C), displays the template for the ticklishness-perception task.



Appendix B

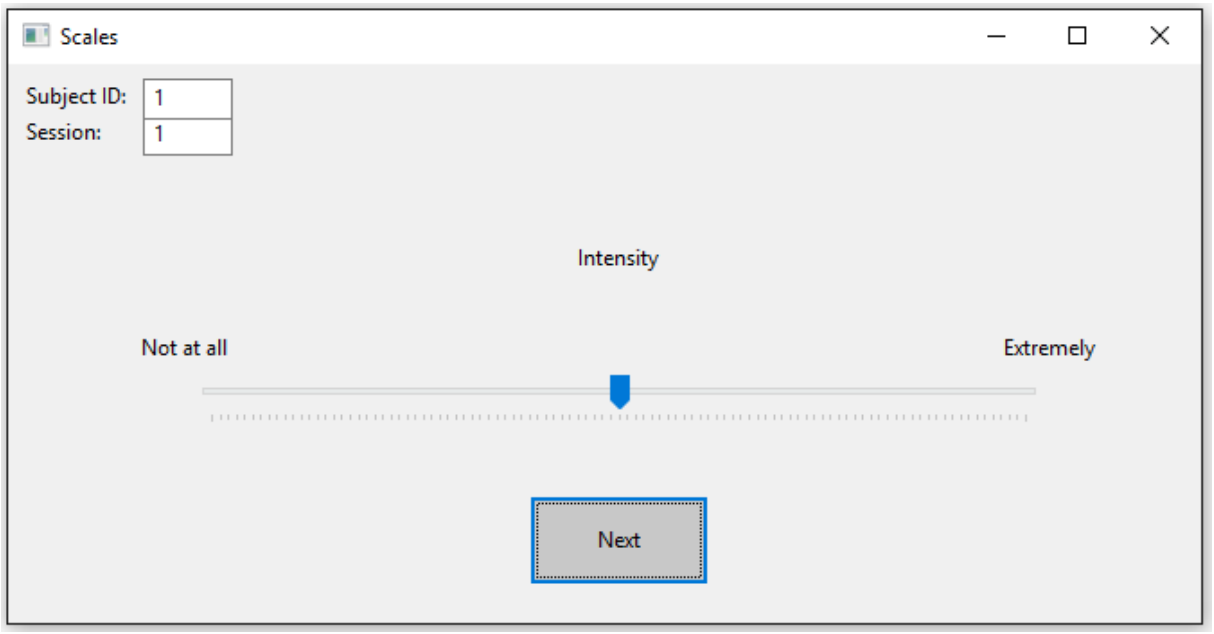
Picture of the different stimulus

This appendix consists of pictures of the stimulus (A) that was used for the three different tasks and the robot with rod attached for the force-perception task (B). (1) displays the brush that was used in the pleasantness-perception task, (2) displays the sharper plastic edge that was used in the ticklishness-perception task, and (3) displays the 3D printed rod that was used in the force-perception task.



Appendix C

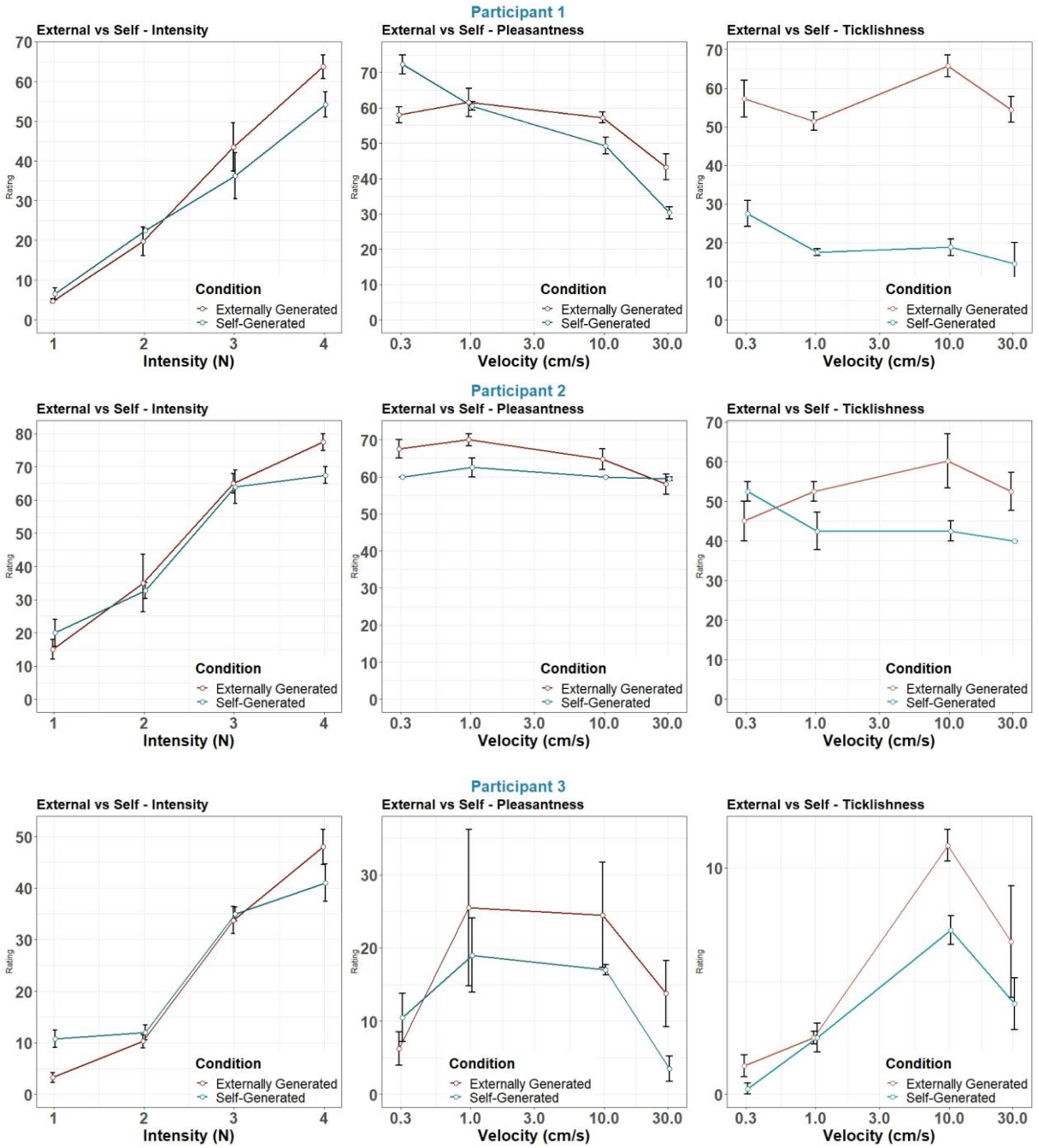
Visual Analog scale example for Intensity (VAS)

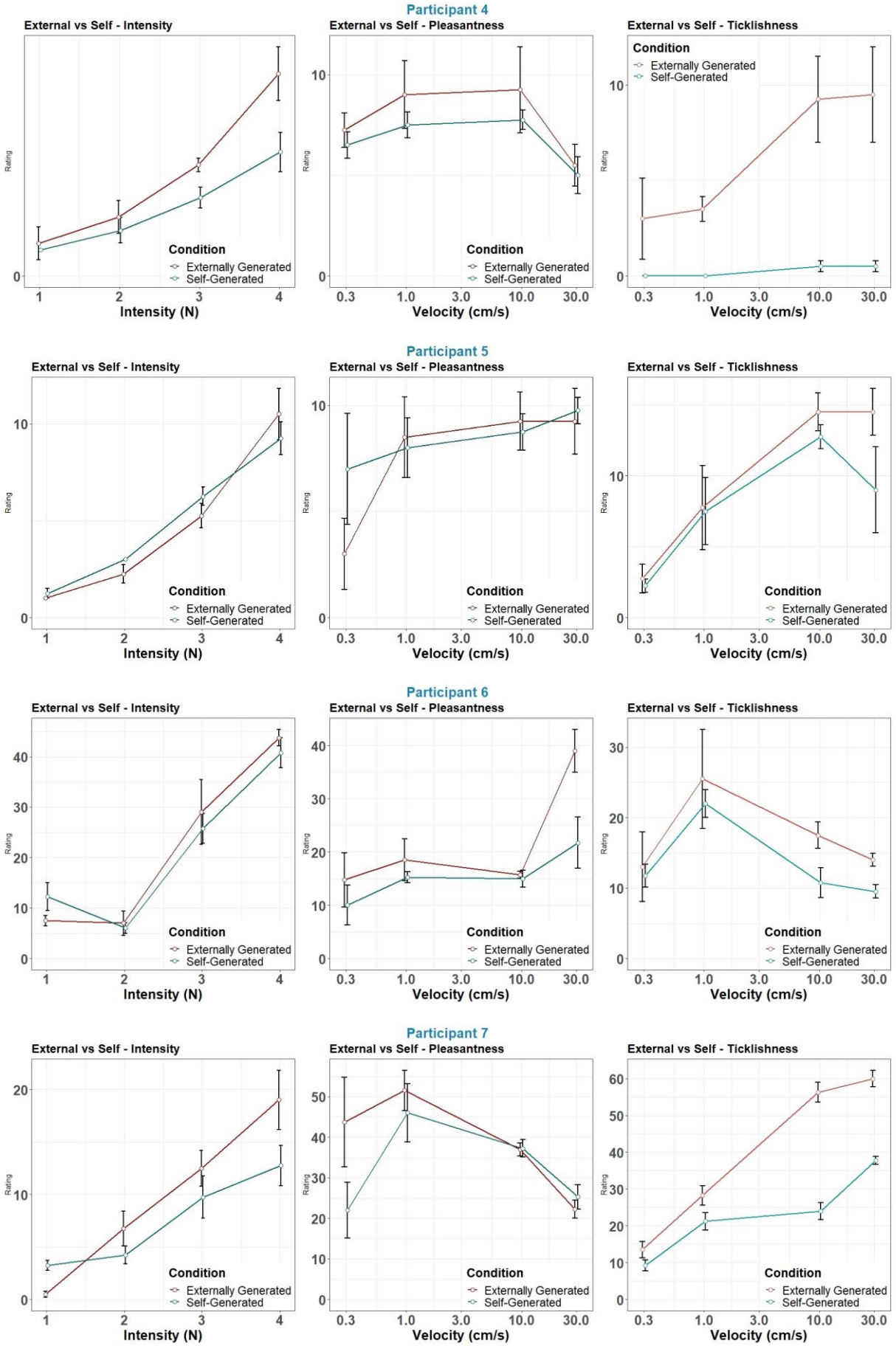


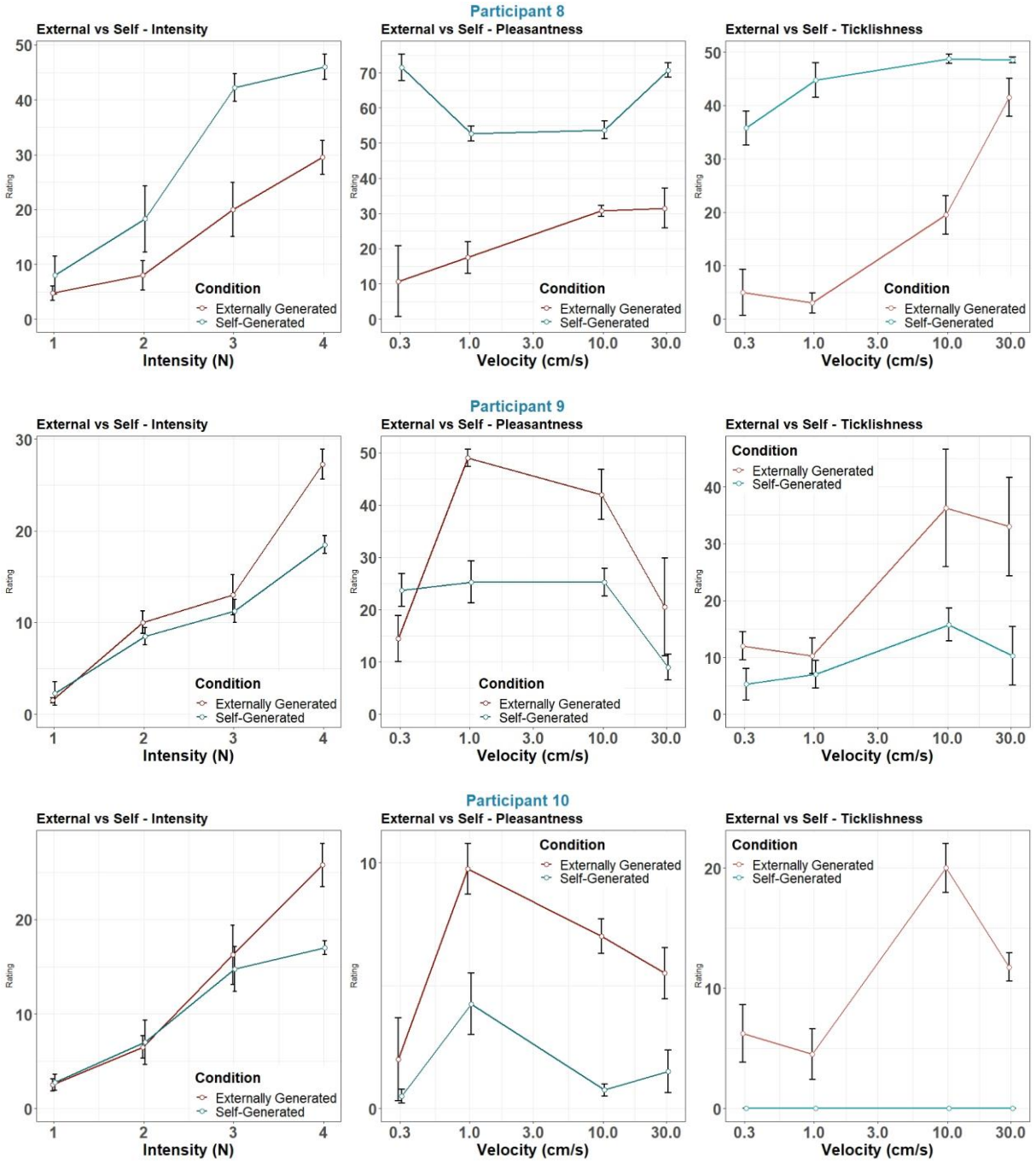
Appendix D

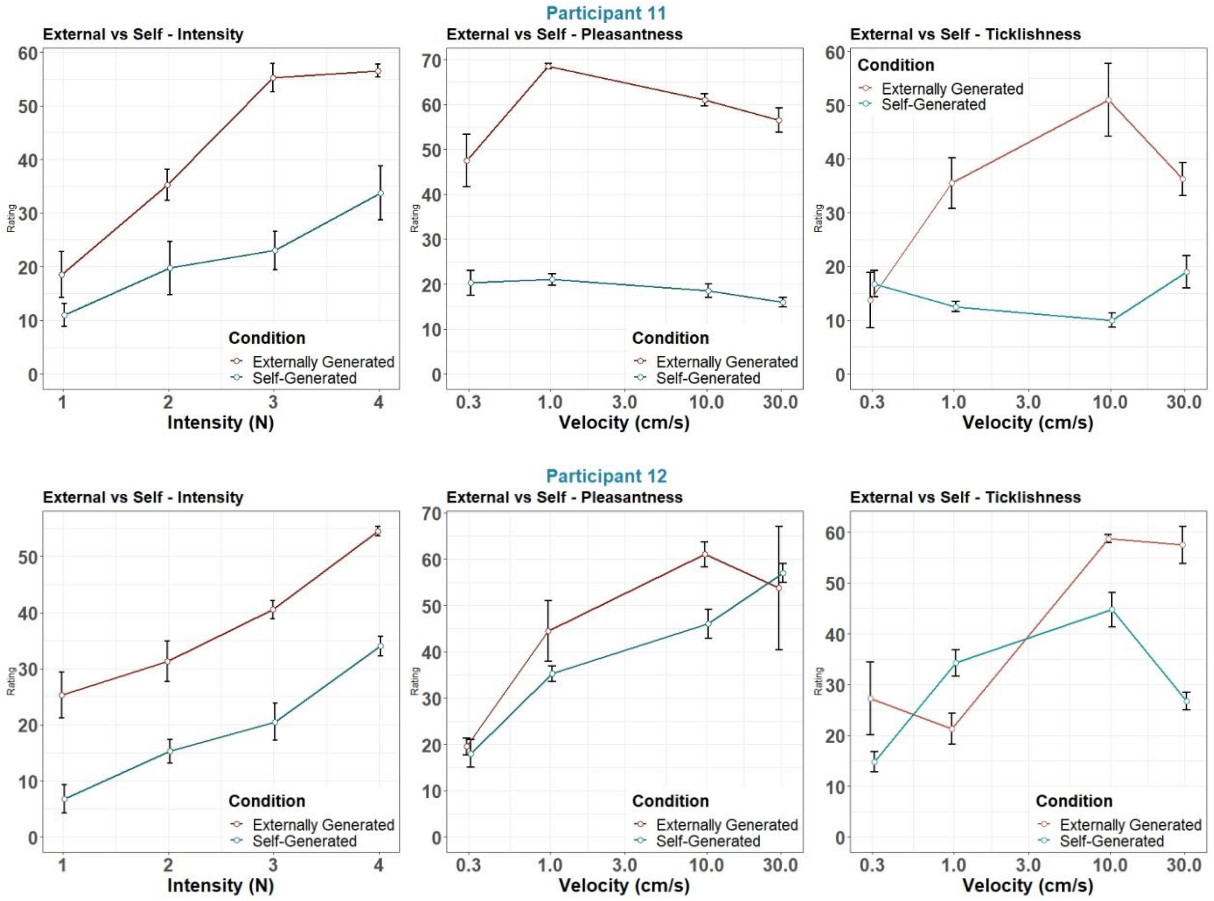
Descriptive data of each participant for each task.

This appendix shows each individual participants Mean and Standard Error of the Mean for each task (force-perception task, pleasantness-perception task, and ticklishness perception task) and condition (self-generated and externally generated condition).




Participant 4
External vs Self - Intensity
External vs Self - Pleasantness
External vs Self - Ticklishness
Participant 5
External vs Self - Intensity
External vs Self - Pleasantness
External vs Self - Ticklishness
Participant 6
External vs Self - Intensity
External vs Self - Pleasantness
External vs Self - Ticklishness
Participant 7
External vs Self - Intensity
External vs Self - Pleasantness
External vs Self - Ticklishness
Rating
Intensity (N)
Velocity (cm/s)
Condition
Externally Generated
Self-Generated


Participant 8
External vs Self - Intensity
External vs Self - Pleasantness
External vs Self - Ticklishness
Rating
Intensity (N)
Velocity (cm/s)
Condition
Externally Generated
Self-Generated
Participant 9
External vs Self - Intensity
External vs Self - Pleasantness
External vs Self - Ticklishness
Rating
Intensity (N)
Velocity (cm/s)
Condition
Externally Generated
Self-Generated
Participant 10
External vs Self - Intensity
External vs Self - Pleasantness
External vs Self - Ticklishness
Rating
Intensity (N)
Velocity (cm/s)
Condition
Externally Generated
Self-Generated


Participant 11
External vs Self - Intensity
External vs Self - Pleasantness
External vs Self - Ticklishness
Rating
Condition
Externally Generated
Self-Generated
Intensity (N)
Velocity (cm/s)
Participant 12
External vs Self - Intensity
External vs Self - Pleasantness
External vs Self - Ticklishness
Rating
Condition
Externally Generated
Self-Generated
Intensity (N)
Velocity (cm/s)

Appendix E

Descriptive statistics for individual participants' attenuation index and SPQ

This appendix shows Attenuation index (AI) for each participant for all attenuation index levels in each task (AI_Force-All, AI_Ticklishness-All, and AI_Pleasantness-All), and for the force and velocity levels that elicited the strongest attenuation for all three tasks (AI_Force_4N, AI_Ticklishness-10_30, and AI_Pleasantness-1). Furthermore, the score of the full SPQ is displayed (SPQ Full Score).

ID	AI_Force-All	AI_Force_4N	AI_Ticklishness-All	AI_Ticklishness-10_30	AI_Pleasantness-All	AI_Pleasantness-1	SPQ Full Score
1	3	9.5	37.6	43.5	1.9	1	31
2	2	10	8.2	15.125	4.6	7,5	30
3	-0.9	7	1.88	3.25	5	6,5	23
4	1.26	3	6.06	8.875	1.06	1,5	6
5	-0.19	1.25	2	3.625	-0.88	0,5	27
6	0.6	3	4	5.625	6.5	3,25	8
7	2.19	6.25	16.4	27.25	6	5,5	17
8	-13	-16.5	-27.2	-18.125	-39.6	-35,25	42
9	2.8	8.75	13.34	21.625	10.7	23,75	9
10	2.4	8.75	10.6	15.875	4.31	5,5	12
11	19.5	22.75	19.5	29.125	39.5	47,5	14
12	18.8	20.5	11.1	22.375	5.6	9,25	18