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Exposure shapes the perception of affective touch

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ABSTRACT

Touch is a common occurrence in our lives, where affective and inter-personal aspects of touch are important for our well-being. We investigated whether touch exposure affects hedonic and discriminative aspects of tactile perception. The perceived pleasantness and intensity of gentle forearm stroking, over different velocities, was assessed in individuals reporting to seldom receive inter-personal touch, and in controls who received touch often. The groups did not differ in their stroking intensity judgements, nor in tactile discrimination sensitivity; however, individuals with low touch exposure evaluated the pleasantness of touch differently. These individuals did not differentiate pleasantness over the stroking velocities in the same way as the control group. The pleasantness curve for the low touch exposure group was significantly flatter and they rated 3 cm/s stroking as significantly less pleasant. Other physiological and questionnaire measures were obtained and the appreciation of touch from familiar persons was positively related to the pleasantness of touch in controls, but this was not found in low touch exposure individuals. This suggests that the association of human caresses from well-known individuals, with the pleasure derived, may depend on continued exposure to it.

1. Introduction

Inter-personal touch forms an important means of social communication (Hertenstein et al., 2006) and bonding (Dunbar, 2010), and it is very often experienced as hedonic. A slow, gentle caress of the skin is widely regarded as highly pleasant (Löken et al., 2009, 2011; Essick et al., 2010; Ackerley et al., 2014a, 2014b; Croy et al., 2016b) and such stroking touch is perceived as rewarding for long durations (Triscoli et al., 2014; Sailer et al., 2016). Furthermore, the appreciation of tactile pleasantness is believed to increase with age (Sehlstedt et al., 2016). Recent studies have investigated pleasant touch in patient groups, such as in autism (Cascio et al., 2008, 2012; Kaiser et al., 2016), in individuals with reduced C-fibers (Morrison et al., 2011), anorexia (Crucianelli et al., 2016), and those undergoing psychotherapy (Croy et al., 2016a). Small, but specific, differences have been found between these groups and healthy controls, where these individuals can readily assess hedonic touch, yet its central processing may be different.

Pleasant tactile sensations are encoded by low-threshold mechanoreceptors in the skin; however, these vary by skin site. In the glabrous skin of the hand, myelinated Aβ afferents code tactile interactions, which usually involve active and exploratory touch, whereas the hairy skin that covers the majority of the body also contains hairs and unmyelinated C-tactile (CT) afferents, and is more involved in receiving touch (Ackerley et al., 2014c, 2014b). Gentle, affective touch is signaled by all low-threshold mechanoreceptors (Löken et al., 2011; Ackerley et al., 2014b), yet the CTs in hairy skin are thought to *directly* encode the pleasant aspects of moving touch (Löken et al., 2009; Ackerley et al., 2014a). CT afferents respond optimally to gentle stroking in the range of 1–10 cm/s, which correspond well with the velocities that are perceived as the most pleasant (Löken et al., 2009; Ackerley et al., 2014a). These fibers respond maximally to touch at skin temperature (Ackerley et al., 2014a), and individuals who spontaneously are asked to stroke their partner or baby do this at CT-optimal velocity (Croy et al., 2016b; Triscoli et al., 2017), suggesting that CT-fibers are tuned to inter-personal caresses. Furthermore, such slow, gentle stroking produces autonomic physiological effects, such as decreases in heart rate (Fairhurst et al., 2014; Triscoli et al., 2017).

In addition to these peripheral mechanisms, central factors can influence the perception of touch. For example, pleasantness ratings for CT-targeted touch were reduced when a repugnant odor was simultaneously presented (Croy et al., 2014), and when a cream was labelled as “basic” in contrast to “rich” (McCabe et al., 2008). A further factor that may influence touch is the frequency of exposure to touch. Field (2010) highlights the requirement for inter-personal tactile interactions in social-emotional and physical development and well-being. In animals, socially naïve and experienced crayfish reacted differently to

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unexpected touch (Song et al., 2006), with socially naïve animals confronting the touch source with raised claws and an elevated posture. Rats that had their whiskers clipped early in life, compared to later, were severely impaired in distinguishing rough from smooth surfaces (Carvell and Simons, 1996). Experience has also been found to affect tactile memory in blind and deaf-blind participants, where performance was related to the age of Braille acquisition (Papagno et al., 2016). Hence, it appears that touch is a basic need and driver of behavior over the lifetime, where touch deprivation can have serious cognitive, social, and developmental consequences (Gallace and Spence, 2010).

In the present study we explored the perception of touch in individuals who rarely experience touch, compared to individuals who experience touch often. Similar to food deprivation enhancing the subjective appeal of food stimuli (Goldstone et al., 2009), and thirst enhancing the pleasantness of images of beverages (Becker et al., 2014), we expected participants reporting a low frequency of current touch experience to perceive an enhancement of the pleasantness of touch. At the same time, the more sensory aspects of touch such as tactile sensitivity and intensity perception were expected to not differ between individuals with low touch exposure and controls.

2. Materials and methods

2.1. Participants

The experiment was approved by the local ethics committee and was performed in accordance with the Declaration of Helsinki. Written informed consent was obtained and participants were paid for their time. Participant were recruited via announcements on hospital and university boards, and via social media, where individuals were sought "who rarely experience touch" for the experimental group, and "who often experience touch" for the control group. A total of 25 participants were recruited for each group.

The self-selection of participants into groups was evaluated by examining their scores on tactile questionnaires (see Section 2.2 for details). Two individuals, one self-assigned to the low touch exposure group and one self-assigned to the control (higher-touch exposure) group, were considered to have wrongly self-selected their respective group. In these cases, both the level of satisfaction in the amount of touch received and the amount of touch experienced in the last week were outside the interquartile range for the group. The participant that was considered to have wrongly self-assigned to the low touch exposure group reported to receive general or tender touch daily, whereas the participant that was considered to have wrongly self-assigned to the higher-touch exposure group reported to receive general or tender touch only monthly or less (for a description of these variables, see Section 2.2). These two participants were therefore moved into the other respective group.

Following this allocation, there were 11 women and 14 men (mean age = 30.5, SD = 12.8) in the low touch exposure group, and 12 women and 13 men in the control higher-touch exposure group (mean age = 31.4, SD = 12.5). Five individuals from the low touch exposure group had a partner, and two had children, compared to 17 individuals with a partner and 8 with children in the control group. 19 individuals in the low touch exposure group and 19 in the control group had a pet. Two participants in the low touch exposure group reported taking psychotropic drugs. These participants were kept in the sample because their symptoms were considered as treated and stable.

2.2. Procedure

Following signing the consent form, participants filled in questionnaires on demographic data, psychopharmacological medication, psychiatric/psychological diagnoses, family status, and several items to assess touch exposure as described in the following. To assess the subjective satisfaction with the amount of touch received, the degree of agreement with the following two 4-point Likert items was collected: "Overall, I am satisfied with the amount of touch I get", and "I wish I would receive more touch". The mean of both items was used to indicate individual 'touch frequency satisfaction'. Another question asked how often participants had received one of the following types of touch in the past week: hand shake, arm around the shoulder, caress, kiss, and hug. These types of touch were illustrated with a line drawing and participants were asked to put a number next to each drawing. The sum of these numbers was calculated to obtain 'touch frequency during the last week'. Another question asked how often the participants had bodily contact with other people. Response alternatives were "more than 10 times a day", "6–10 times a day", "2–5 times per day", "once a day", "more than once a week", "once a week", "1–3 times per month", "less than once a month".

A further question asked how often participants had tender bodily contact with a partner, family member or close friends. Response alternatives were "more than 30 min a day", "more than 10 min a day", "once a day", "more than once a week", "once a week", "once a month", "less than once a month", "never". Responses to those two questions were grouped together to form categories of approximately equal number of cases, which were "weekly", "daily", and "monthly or less". If participants received either "ordinary" body contact or tender body contact at least daily, they were put into the category "daily" (and analogously for "weekly"). The resulting sum from these two last questions was called 'general touch frequency'.

Participants were then seated comfortably with their left forearm resting in a prone position on a vacuum pillow that was adjusted to their arm. They were prevented from seeing their arm by occluding glasses. Hairs on the forearm were removed with a razor prior to a monofilament test, to measure tactile discrimination thresholds. Nine monofilaments ranging from 13.7 mN to 0.08 mN were applied in a staircase method (Jönsson et al., 2015). The experimenter started with the strongest monofilament and asked the participants to verbally report whether they could feel it or not. In the case of a positive answer ("yes"), the experimenter continued with the next weaker monofilament, and in case of another positive answer with the next weaker, until the participant reported "no". The corresponding stimulus at this point represented the first reversal point, at which the experimenter continued with the next stronger monofilament. As soon as the participants answered positively again, the procedure reversed again and the experimenter continued with the next weaker microfilament in decreasing order. Six reversal points was collected, of which the median of the last four were used as a measure of the individual tactile discrimination threshold.

Next, electrocardiogram (ECG) electrodes were applied below the participants' right clavicle, and below the left and right costal arch. ECG was recorded at 1000 Hz (using PowerLab equipment with Chart Pro software; AD Instruments, Dunedin, New Zealand). A distance of 10 cm was marked with a pen in the middle of their arm, to designate the area of skin to be stroked. Participants were instructed to look straight across the room and to concentrate on the upcoming tactile stimulation, which was applied with a soft brush of 7.5 cm width. Prior to the experiment, the experimenter practiced delivering controlled brush strokes at different velocities (guided by a visually-timed meter), with a constant pressure of 0.4 N by brushing on a weighing scale. The experimenter manually delivered brush-strokes over the arm in a proximal-distal direction, at 5 different velocities: 0.3, 1, 3, 10, or 30 cm/s. Each velocity was presented 5 times in a pseudo-randomized order. The brushing velocity for the experimenter was guided by a visual meter on a monitor, which was not visible to the participant.

Following each stimulation, the participant rated the pleasantness and then the intensity of the brush stroke on a visual analog scale (VAS), presented on a screen in front of them, using a mouse in their right hand. Above the VAS for pleasantness, the question "How did you experience the recent stimulation?" was displayed, and the endpoints were "unpleasant" (scored as −10) and "pleasant" (+10). Above the

VAS for intensity, the question "How intense was the recent stimulation?" was displayed, and the endpoints were "weak" (−10) and "strong" (+10). ECG was recorded from the onset of the first brushing trial to the offset of the last brushing trial, including the rating period. The average recording time across both groups was 13.5 mins.

Subsequently, participants filled in several questionnaires: the Beck Depression Inventory (BDI; Beck and Steer, 2002), the Arnetz-Hasson stress questionnaire (Andersson et al., 2009) collecting subjective reports of how stressed one feels "right now", and the Social Touch Questionnaire (STQ) (Wilhelm et al., 2001), assessing comfort and preferences regarding social touch. Lower scores on the STQ indicate a preference for social touch, whereas higher scores are associated with rating social touch as unpleasant and avoiding it across a variety of situations. In our analysis, positively-worded questions are scored in reverse (Wilhelm et al., 2001). Scores were also calculated for items pertaining to three different sub-factors identified in the STQ (Vieira et al., 2016), namely the dislike of physical touch, appreciation of familiar physical touch, and liking of public physical touch.

2.3. Data analysis

The satisfaction with touch frequency, sum of touch in the last week, Arnetz-Hasson score, BDI score, the STQ total score and subscores for both groups, and heart rate measures were compared using independent *t*-tests. Tactile thresholds were compared by a Mann-Whitney *U* test. Frequencies for the three different categories of "general touch frequency" were compared between both groups by means of Fisher's exact test.

ECG heart rate (HR) data were averaged separately for the first 3 min and the last three minutes of stimulation. For these intervals and for each participant, the mean heart rate and mean standard deviation of inter-beat intervals as a measure of heart rate variability (HRV) were calculated. The difference between the last and the first 3 min was calculated, constituting the variables "HR change" and "HRV change". Due to the occurrence of outliers, these data were winsorized (Ghosh and Vogt, 2012), i.e. values above the upper limit (75th percentile + 1.5 × interquartile range) of each group were replaced with the value corresponding to the upper limit, and values below the lower limit (25th percentile − 1.5 × interquartile range) were replaced with the value corresponding to the lower limit of each group. Independent-sample *t*-tests were used to compare the HR change and HRV change between both groups.

Pleasantness and intensity ratings from the brush stroking were submitted to two separate 2 × 5 repeated-measure ANOVAs with the group as a between-subjects factor (levels: low touch exposure, control) and stroking velocity as the within-subjects factor (levels: 0.3, 1, 3, 10, 30 cm/s). Due to violation of the sphericity assumption, a multivariate approach to repeated measures was used. Significant interactions were followed up by pairwise *t*-tests for independent samples and values of $p < 0.05$ were considered significant.

Since pleasantness ratings in previous similar experiments have been found to follow a quadratic fit (Löken et al., 2009, 2011; Morrison et al., 2011; Ackerley et al., 2014a, 2014b; Sehlstedt et al., 2016), the pleasantness ratings for each velocity were fitted subject-wise to a constant, and linear or quadratic curve. The different models were then compared with the Akaike Information Criterion (AIC). The change in this measure (Delta-AIC) was used as a measure of each model relative to the best model (the model with the lowest AIC), and was calculated for each participant. Delta-AIC values smaller than 2 suggest substantial support for the model, values between 3 and 7 indicate considerably less support, and values larger than 10 indicate that the model is very unlikely (Burnham and Anderson, 2004). Accordingly, the model with the smallest delta-AIC is the best-fitting model. Based on these data, it was determined whether the quadratic model better described the data of the control group, as compared to the experimental group. To this aim, the frequency with which the quadratic model was found to be the best one (i.e., participants for which delta-AIC for the quadratic model was 0) was compared for both groups by means of a chi-square test.

An additional analysis was performed to investigate how strongly the data were curved (quadratic) and whether the curvature was different between the groups. The curvature coefficient was defined by the coefficient of the second order term in the quadratic fit for all participants in which the quadratic model was the best (as indicated by Delta-AIC = 0) and was set to zero for all other participants. The mean of the curvature coefficients in each group was tested against zero with one-sample-t-tests, and the coefficients of both groups were compared with an independent *t*-test.

We used discriminant function analysis to investigate whether our measures could predict if a participant belonged to the low touch exposure or control group. We previously defined these groups using our touch frequency and satisfaction measures, but wanted to explore whether the pleasantness ratings, questionnaire data, and heart rate physiology measures could also be used to classify participant tendencies. For the measures that significantly predicted group membership, further relationships were explored. We also conducted regression analyses that included an interaction term (with group), for each variable. This was to determine significant group interactions per variable and to follow these up in subsequent analyses. The measures included were correlated using Pearson's correlation. Correlations were made on the full group (low touch exposure group and controls together) to investigate group-wide trends, and, separately for each group (where the previous analyses showed significant effects).

For all statistical comparisons, effect sizes were calculated as Cramer's V for non-parametric tests, Cohen's d for *t*-tests, and partial Eta squared for analyses of variance.

3. Results

3.1. Differences between low touch exposure group and control group

There was a significant difference between the general touch frequency categories for the low touch exposure group and the control group ($p < 0.001$; Cramer's V = 0.73) (see Table 1). Satisfaction with touch frequency and the sum of touch received in the last week were significantly higher in the control group than in low touch exposure group (see Table 2).

Both groups did not differ in their scores on the Arnetz-Hasson stress questionnaire, BDI, STQ total score and sub-factors, and tactile threshold (all p's > 0.1). They were also not different regarding their HR change and HRV change (Table 2).

Stroking over the five velocities produced a significant difference in the pleasantness ratings ($F(4,45) = 10.1$, $p < 0.001$, $\eta^2 = 0.47$). Further, pleasantness was rated differently between the groups, where a significant interaction between velocity and group was found ($F(4,45) = 2.8$, $p = 0.037$, $\eta^2 = 0.20$) (Fig. 1, left). Post-hoc *t*-tests revealed that the ratings for velocities differed only for the 3 cm/s velocity ($p = 0.041$), which the low touch exposure group rated as significantly less pleasant. The ratings did not differ between groups for 0.3 cm/s ($p = 0.127$), 1 cm/s ($p = 0.690$), 10 cm/s ($p = 0.211$), and 30 cm/s ($p = 0.414$). Intensity was rated as lower for the slower stroking velocities (main effect for velocity $F(4,45) = 3.464$; $p = 0.015$, $\eta^2 = 0.24$) by both groups. There was no interaction between group

Table 1
Self-reported general frequency of touch, for low touch exposure participants and for controls. There was a significant difference in the touch received between the groups.

Group	General touch frequency		
	Monthly or less	Weekly	Daily
Low touch exposure	5	17	3
Controls	0	4	21

Table 2
Mean (median) and standard deviation for outcome measures in low touch exposure individuals and control participants. Significant results are shown in bold.

Measure	Low touch exposure		Controls		Statistical differences	Effect size
	Mean	SD	Mean	SD	Test details and *p*-value	Eta squared
Satisfaction with touch frequency (range 0–4; lower scores = less satisfaction)	1.8	0.7	3.0	0.8	**t = −5.4, df = 48, p < 0.001**	0.38
Sum of touch received in last week (times/week)	13.3	9.7	92.0	101.5	**t = −3.9, df = 46, p < 0.001**	0.25
Arnetz-Hasson stress score (range 0–700; lower scores = less stress)	36	10	40	12	t = −1.3, df = 48, p = 0.201	0.03
Beck Depression Inventory score (range 0–63; lower scores = less depressed)	13	12	11	11	t = 0.5, df = 48, p = 0.578	0.01
Social Touch Questionnaire (STQ) mean score (lower scores = favor social touch, also for following three STQ factors)	2.3	0.6	2.2	0.5	t = 0.9, df = 48, p = 0.352	0.02
STQ – factor dislike of physical touch	2.3	1.0	1.9	0.6	t = 1.5, df = 48, p = 0.128	0.05
STQ – factor liking of familiar physical touch	2.0	0.5	2.1	0.8	t = −0.5, df = 48, p = 0.563	0.01
STQ – factor liking of public physical touch	2.7	0.7	2.7	1.0	t = 0.3, df = 48, p = 0.933	0.00
Heart rate change (ms)	−1.0	3.0	−0.2	3.2	t = −0.9, df = 48, p = 0.360	0.02
Heart rate variability change (ms)	−8.8	16.6	−4.5	25.1	t = −0.7, df = 48, p = 0.477	0.01
Monofilament threshold (mN) (median values)	2.6	0.7	2.3	0.6	U = 248, p = 0.206	0.03

and velocity for stroking intensity ($F(4,45) = 2.5$, $p = 0.057$, $\eta^2 = 0.18$) (Fig. 1 right).

The quadratic model provided the best fit to the pleasantness ratings for 14 low touch exposure participants and 18 controls. These frequencies were not different for both groups (Chi-square (1) = 1.4; $p = 0.239$; Cramer's V = 0.17). Thus, irrespective of the group, the quadratic model was the best of the three models in 64% of all cases. The mean curve coefficient of the pleasantness ratings was −0.123 (SD = 0.238) for the low touch exposure group, and −0.329 (SD = 0.359) for the control group. The quadratic curvature was significant in both groups (low touch exposure: $T(24) = -2.6$; $p = 0.017$; Cohen's $d = -0.52$; controls: $T(24) = -4.6$; $p = 0.001$; Cohen's $d = -0.91$), but significantly more curved for the controls ($T(48) = 2.4$; $p = 0.021$; Cohen's $d = 0.69$).

3.2. Exploration of measures that can predict group membership

Discriminant function analysis was performed to ascertain whether any of the variables measured in the experiment could predict the group membership (i.e. compared to the measures used in defining the low touch exposure or control groups). We found that the pleasantness ratings for stroking at 3 cm/s ($\chi^2 = 4.19$, $p = 0.041$) and the pleasantness ratings curve coefficient ($\chi^2 = 7.56$, $p = 0.006$) were significant predictors of whether a participant was classed in the low touch exposure or control group. Here, the lower the pleasantness rating for stroking at 3 cm/s, the more likely the participant was classed as belonging to the low touch exposure group. Similarly, the flatter the pleasantness ratings curve, the more likely the participant was classed as belonging to the low touch exposure group. None of the ratings for the other stroking velocities, the physiological heart rate measures, and the questionnaire scores contributed significantly to determining group membership.

3.3. Correlations of pleasantness ratings with questionnaire scores, and physiological measures

To investigate further relationships in the measures that were significant in determining touch exposure and its effects, we correlated the pleasantness ratings for stroking at 3 cm/s and the pleasantness ratings curve coefficient with the other measures. When a significant interaction between group (low touch exposure vs. control) and a measure was found, we followed up the whole-group correlation by conducting further correlations separately in each group. Each correlation measure in Table 3 showed a significant interaction with the group at $p < 0.01$, allowing separate correlations to be performed per group. For the questionnaire items, significant correlations were found for the control group only. Here, higher pleasantness ratings for stroking at 3 cm/s were significantly correlated with a higher appreciation of familiar touch ($p = 0.006$). Further, the rounder the pleasantness ratings curve, the lower the dislike of physical touch ($p = 0.010$). Conversely, there was an overall significant correlation between the difference in HR between the first and last minutes of stroking for both the pleasantness measures, but this effect was driven by the low touch exposure group. Here, lower pleasantness ratings for stroking at 3 cm/s ($p = 0.016$) and a flatter pleasantness curve ($p = 0.009$) both were associated with increases in HR change.

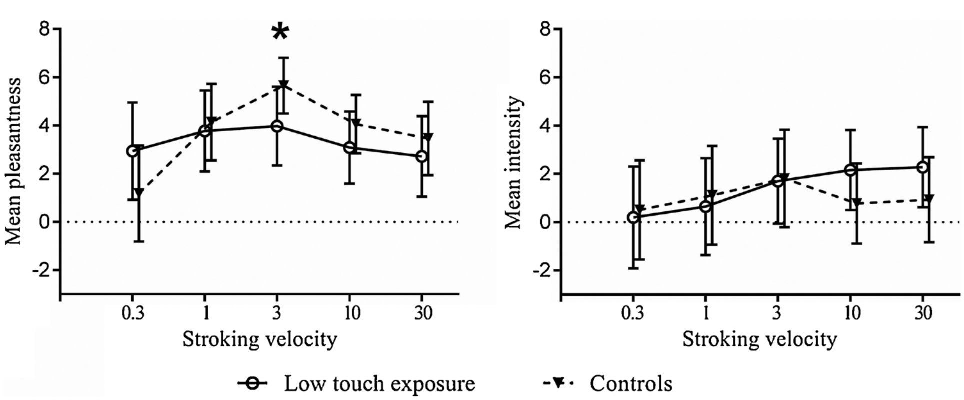

Fig. 1. Mean pleasantness (left) and intensity (right) ratings over the stroking velocities, for each group. The curve for pleasantness ratings was significantly flatter for the low touch exposure individuals, whereas no differences were found between groups for touch intensity. Error bars denote standard deviation.

Table 3
Correlations between pleasantness ratings (stroking at 3 cm/s and pleasantness curve coefficient) and questionnaire items and heart rate variables. Correlation coefficients (effect sizes) are shown, for the whole sample and by group. Asterisks show correlations that are significant at the *p < 0.05 level and **p < 0.01 level (two-tailed).

Measures	Pleasantness ratings for stroking at 3 cm/s			Curvature of pleasantness ratings line		
	All participants (n = 50)	Low touch exposure group (n = 25)	Control group (n = 25)	All participants (n = 50)	Low touch exposure group (n = 25)	Control group (n = 25)
Appreciation of familiar touch (STQ)	0.173	−0.137	0.536**	0.134	0.174	0.184
Liking of public physical touch (STQ)	−0.034	−0.184	0.110	−0.107	−0.270	−0.049
Stress ratings	0.002	−0.050	−0.065	0.000	−0.044	0.146
Heart rate change	−0.312*	−0.478*	−0.248	0.285*	0.513**	0.276
Heart rate variability change	0.031	−0.062	0.061	−0.062	−0.212	0.064

The stress ratings were also correlated with the STQ sub-factors. For the whole participant population (n = 50), stress ratings correlated with ratings of physical touch (r = 0.348, p = 0.013) and familiar touch (r = 0.272, p = 0.056). For both STQ items, the control group (n = 25) drove the correlation, where decreased stress correlated significantly with liking public physical touch (r = 0.502, p = 0.011) and appreciating familiar touch (r = 0.516, p = 0.008).

4. Discussion

Individuals with low touch exposure were comparable to controls in sensory aspects of touch, such as tactile sensitivity and the perceived intensity of stimulation; however, they differed regarding the hedonic aspects of touch. Contrary to our hypothesis, they did not rate touch as more pleasant than controls, but as less pleasant, in particular when it was given at CT-optimal velocities. Moreover, the curvature of pleasantness ratings for different velocities was generally flatter in individuals that rarely received touch. This indicated that they did not discriminate affective touch well, i.e. differences over the stroking velocities, which is thought to underpin the normal perception of gentle, dynamic touch (Morrison et al., 2011). At the same time, the pleasantness curves in both groups were best described with a quadratic fit. This suggests that the same affective processes may underlie the ratings in both groups, but that these are diminished in the individuals with low touch exposure.

In the control group, the increased pleasantness of CT-targeted touch was related to a higher appreciation of familiar touch (as measured in the self-report questionnaires). Thus, the more the control participants reported enjoying touch from persons well-acquainted to them, the more they enjoyed being stroked at a velocity corresponding to a human caress. On the contrary, there was no such coupling in individuals with low touch exposure. In controls, a stronger appreciation of familiar touch was also associated with less subjectively-experienced stress, which was not the case in low touch exposure individuals. Situational experience with inter-personal touch was higher in control participants, and this situational experience may lead to both a stronger association of CT-optimal velocities with human caresses by close-ones (cf. Croy et al., 2016b), and to increased pleasantness derived from this type of touch. However, the low touch exposure group nevertheless reported the ability to appreciate familiar touch. Hence, the more social and inter-personal touch is experienced, the more it impacts on our perception of affective touch. This is akin to the 'use it or lose it' hypothesis, which is often used in promoting intellectually-stimulating activities to combat age-related cognitive decline (Hultsch et al., 1999; Rohwedder and Willis, 2010; Nexø et al., 2016). The active maintenance of cognitive activities helps mental function, and the same process may be at work in inter-personal touch, where those who experience less frequent touch interactions *socially* show decreases in *affective* touch processing, as found in the present work.

Physiologically, an increase in the sensitivity to stroking was associated with a calming effect, through decreases in heart rate over time. Conversely, lower derived pleasantness for stroking at 3 cm/s and a flatter pleasantness curve were significantly correlated with an increased heart rate, but these effects were driven by the low touch exposure individuals. Recent studies have shown that stroking at CT-optimal velocity produced a calming effect (through decreased heart rate) in infants (Fairhurst et al., 2014) and adults(Triscoli et al., 2017; Pawling et al., 2017). Thus, the individuals with low touch exposure derived less pleasantness through touch, and in turn, were not relaxed by tactile stimulation. However, our study is limited in that we did not distinguish heart rate changes for different stroking velocities; rather the results reflect heart rate changes to receiving stroking touch in general. It is of interest to explore this further and understand the mechanisms behind these effects.

In our present work, there did not seem to be one underlying factor accounting for the differences between individuals with low touch exposure and the control group. This may be due to the low touch exposure group consisting of a heterogeneous sample, where their lack of touch stems from a variety of reasons. These may include situational variables (e.g. lack of family, length of time without a partner), personality traits (e.g. beliefs and perceptions about affective touch), and psychological issues (e.g. autistic traits), many of which we were not able to control for presently. There were differences in the family situation between groups, where only 20% of the individuals in the low touch exposure group had a partner and/or child, whereas for the control group, this was 72%. On all the other measures (e.g. age, stress, depression, attitudes towards social touch, heart rate measures, and tactile sensitivity), the groups did not differ.

We do not know for how long and why individuals felt that they lacked touch, but the low touch exposure group *perceived* themselves as having fewer touch interactions, and we relate this to their hedonic evaluation of touch. This perception, whether it is valid or not, represents a social touch incongruity between what they have and what they want, as seen in the significant decreases in touch frequency satisfaction and touch received, compared to the control group. The disparity in the low touch exposure group's level of social touch experience seems to, in part, be driven by situational factors, be they self-enforced (e.g. choosing not to have a partner) or not (e.g. would like a significant other, but they do not have one). In turn, their situation may reflect an underlying psychological characteristic, for example autistic traits.

The present study is limited by the self-reported touch differences, although our analyses showed that pleasantness measures (ratings at 3 cm/s and the pleasantness curve coefficient) could predict whether an individual received a lower amount of touch. This may be used as a more impartial diagnostic to assess an individual's engagement with touch. While no systematic assessment of psychopathology (including autistic traits) was performed, individuals from both groups were similar regarding BDI scores and self-reported psychological/psychiatric diagnoses. Previously, autistic traits have been found to be related to differences in affective touch perception (Croy et al., 2016) and processing (Kaiser et al., 2016). It can therefore not be excluded that autistic traits underlie both the low exposure to touch in daily life and the different evaluation of hedonic touch. Future studies should look more closely into the relationship between these factors.

The current study only assessed touch frequency in adults at a given point in time. It is not known whether these individuals had a history of decreased touch exposure, or whether they actively chose to avoid touch. These factors may contribute directly to the perception of affective touch over time, especially as Sehlstedt et al. (2016) found an increase in affective touch appreciation with age that was related to the extent of tactile evaluation. Increased inter-personal touch in adolescents has also been associated with decreased aggression (Field, 1999). Furthermore, pleasant touch has been shown not to satiate, where participants both like and want touch over repeated exposure (Triscoli et al., 2014), where long-lasting gentle touch shows increased activity in reward-related cortical areas (Sailer et al., 2016). How touch exposure changes over time would be an interesting target for further research, where the incidence of inter-personal touch from childhood, and throughout the lifespan, may affect how we perceive affective touch in the long-term.

5. Conclusions

Presently, we find that individuals with self-reported low touch exposure show differences in their hedonic evaluation of touch. However, they show few differences on general touch measures, such as tactile sensitivity, as compared to controls. It seems that their affective touch appraisal may be influenced by the amount of inter-personal touch they receive. This shows the importance of inter-personal and social touch in affective tactile processing.

Declaration of interest

Both authors declare no actual or potential conflicts of interest.

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