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Good vibrations: Global processing can increase the pleasantness of touch.

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Abstract

Visual-tactile carry-over effects of global/local processing (attention to the whole, versus the details) have been reported under active touch conditions. We investigated whether carry-over effects of global/local processing also occur for passive touch and whether global/local processing has differential effects on affective and discriminative aspects of touch. Participants completed two tactile tasks involving pleasantness rating and discrimination of a set of tactile vibrations before and after completing a version of the Navon task that encouraged a focus on the global (*n* = 30), local (*n* = 30), or both (*n* = 30) features of a series of visual stimuli. In line with previous research suggesting a link between global processing and positive emotion, global processing increased pleasantness ratings of high (but not low) frequency tactile vibrations. Local processing did not improve the ability to discriminate between vibrations of different frequencies, however. There was some evidence of a tactile-visual carry-over effect; prior local processing of tactile vibrations reduced global precedence during the Navon task in the control group. We have shown carry-over effects of global versus local processing on passive touch perception. These findings provide further evidence suggesting that a common perceptual mechanism determines processing level across modalities and show for the first time that prior global processing affects the pleasantness of touch.

Keywords: global processing; local processing; discriminative touch; affective touch; attention.

We experience a range of touch sensations in day to day life, from the feeling of clothing against our skin, to the feeling of tactile vibrations from electronic devices such as mobile phones. Our affective appraisals of touch make a difference to how we feel, e.g., how comfortable we feel in our clothes and how much we enjoy using electronic devices (Essick et al., 2010; Hempel & Altinsoy, 2005; Koskinen, Kaaresoja & Laitinen, 2008). This emotional aspect of touch perception is distinct from discriminative touch, which refers to the perceptual attributes of tactile stimulation, linked to quantifiable, physical aspects of the stimuli (see Essick et al., 2010).

Both aspects of touch perception depend on a combination of incoming sensory information (i.e., “bottom-up” factors), and higher-order cognitive, or “top-down” factors, such as attention and expectations. Manipulating spatial attention towards the location of touch improves participants’ ability to discriminate between continuous and pulsed tactile stimulation, for example (Spence, Nicholls, Gillespie & Driver, 1998; see also Johansen-Berg & Lloyd, 2000) and manipulating expectations alters affective appraisals of touch. For example, McCabe, Rolls, Bilderbeck, and McGlone (2008) found that when participants were told that a skin cream was a “rich moisturizing cream”, pleasantness ratings were higher compared to when they were told the same cream was “basic”. The purpose of the current study was to determine whether a different top-down factor, namely global versus local processing, also impacts on affective and discriminative touch perception.

People can pay attention to the same object in different ways, by zooming out and paying attention to the whole, or by zooming in and paying attention to the details (Forster, 2011). One function of attention is to select relevant information in the world for further processing (c.f. Chun, Golomb & Turk-Browne, 2011; Styles, 2005) and attention is therefore closely linked with conscious perception (e.g., Posner, 1994; Velmans, 1996). Whereas a broad attentional scope may heighten the perception of the whole, or “global” form of a stimulus (seeing the forest rather than the trees), a narrow attentional scope may heighten the perception of the details, or “local” elements of a stimulus (seeing the trees rather than the forest, see Robertson, Egly, Lamb & Kerth, 1993). The distinction between global and local perceptual processing has its roots in ancient philosophy (e.g., Kant, 1781/1999) and was later raised by the Gestalt psychologists (e.g., Wertheimer, 1997) who argued that the perception of global forms precedes the perception of local elements. In line with this idea, Navon (1977) found that people were faster to identify global, than local features of hierarchical visual stimuli (e.g., large letters made up from a number of smaller letters, see Figure 1). Researchers have since demonstrated that this global precedence effect is moderated by the size of the global form (Kinchla & Wolfe, 1979) and the size and number of local features (e.g., Martin, 1979; Kimchi, 1992).

Global versus local processing are linked with positive and negative emotions. Self-reported positive mood and optimism are associated with global processing (e.g., Basso, Schefft, Ris & Dember, 1996; Yovel, Revelle & Mineka, 2005). In addition, positive mood states (induced by writing about a positive life event or watching a positive film clip) have been found to enhance global processing (e.g., Fredrickson & Branigan, 2005; Gasper & Clore, 2002). It has been suggested that happy moods enhance global processing by broadening the scope of attention (Fredrickson & Branigan, 2005) and there is some evidence to suggest that this is the case (e.g., Rowe, Hirsh & Anderson, 2007; Wadlinger & Isaacowitz, 2006). In contrast, there is evidence that negative emotions narrow the scope of attention (e.g., Callaway & Dembo, 1958; Derryberry & Tucker, 1994). Indeed, self-reported depression, trait anxiety and an obsessive-compulsive personality are associated with a local processing style (e.g., Basso et al., 1996; Derryberry & Reed, 1998; Yovel, et al., 2005).

It has been suggested that the link between emotion and attentional scope could be bi-directional (Srinivasan & Hanif, 2010). That is, a broad scope of attention might promote a positive mood whereas a narrow scope of attention might promote a sad mood (c.f. Bar, 2009). In line with this idea, Srinivasan and colleagues found carry-over effects of global versus local processing on emotional face recognition. Attending to global features of Navon stimuli improved participants' ability to recognise happy faces, whereas attending to local features improved participants' ability to recognise sad faces (Srinivasan & Hanif, 2010; Srinivasan & Gupta, 2011). Srinivasan and colleagues interpreted these findings as evidence that emotional and global/local information processing reciprocally interact.

Within modality (visual-visual) carry-over effects of global/local processing on face recognition have been reported in other studies (e.g., Lewis, Mills, Hills & Weston, 2009; Macrae & Lewis, 2002; Weston, Perfect, Schooler & Dennis, 2008) and have been explained in terms of transfer-appropriate processing shifts, given that holistic processing has previously been found to benefit face encoding (e.g., Macrae & Lewis, 2002). According to Forster and Dannenberg's (2010) model of global versus local processing (GLOMO^{sys}), carry-over effects occur because global and local processing are content free styles of perception which involve separate cognitive systems. When the global or local system is active, it remains active and can impair or facilitate performance on other tasks, depending on whether the second task requires the same level of processing. Forster and Dannenberg suggest that processing styles carry-over to other, un-related tasks without participants' awareness, representing cases of procedural priming.

The distinction between global and local processing is thought to apply across the senses. For example, when we touch something, we can feel its overall shape, or the details of its texture (see for example Lakatos & Marks, 1999; Lederman & Klatzky, 1990). Indeed, there is evidence that the same gestalt grouping principles thought to govern visual perception (e.g., completion, proximity and emergence) also apply in the auditory (see Dyson, 2009) and tactile modalities (see Gallace & Spence, 2011 for a review). It has been argued that a common perceptual mechanism determines whether information is processed at a global or local level across sensory modalities (e.g., Bouvet, Rousett, Valdois, & Donnadieu, 2011; Ivry & Robertson, 1998;). In line with this argument, the extent of global precedence during visual and auditory tasks is positively correlated (Bouvet et al., 2011). However, more evidence is needed to establish whether common mechanisms do indeed control the level of processing across other sensory modalities, including touch (c.f. Bouvet et al., 2011).

Forster (2011) reported a series of experiments suggesting that global/local carry-over effects occur across sensory modalities. For example, attending to the global, versus local features of Navon stimuli, affected how participants subsequently processed tactile information and vice versa. In Forster's experiment, participants initially completed a version of the Navon task which required attention to the global, local or both features of the stimuli. Next, participants were asked to touch an object whilst wearing a blindfold in order to identify it. The object consisted of four small plastic boxes, glued to a piece of cardboard to make up a larger square. Whilst participants touched the object, two experimenters unaware of the condition rated the extent to which they touched the overall shape versus the details. After focusing on the global features of the Navon stimuli, participants were more likely to touch the overall shape, rather than the details of the object and listed fewer details when they were later asked to describe the object. In a subsequent experiment, Forster reported carry-over effects in the reverse direction, i.e., after touching the overall shape, versus the details, or both aspects of an object, participants were more likely to match Kimchi-Palmer stimuli (large shapes, made up from a number of smaller shapes, Kimchi & Palmer, 1982) on the basis of their global, than their local features and showed stronger global precedence during the Navon task. To our knowledge, the visual-tactile carry-over effects of global/local processing reported by Forster (2011) have not been replicated.

In the current study, we attempted to replicate Forster's finding of visual-tactile global/local carry over effects, but were interested in how global/local processing affects subjective perceptions of passively received tactile stimulation, which was the same for all participants (rather than how global/local processing affects how one actively touches an object). We have previously found that encouraging different attentional states (e.g., internally versus externally focused attention, and mindful versus non-mindful body-focused attention) affects the subsequent perception of tactile vibrations, under passive touch conditions (Mirams, Poliakoff, Brown & Lloyd, 2011; Mirams, Poliakoff, Brown & Lloyd, 2013). However, to our knowledge, the carry-over effects of global/local attention on affective appraisals of passive touch have not been investigated. The use of tactile vibrations allowed full control over the stimulation delivered and has ecological validity; in recent years, there has been growing interest in the pleasantness of vibrotactile stimulation as haptic feedback has been incorporated into electronic devices such as mobile phones and gaming consoles (e.g., Koskinen et al., 2008).

Participants rate soft and smooth stimuli (e.g., silk material, cosmetic brushes) as feeling more pleasant than rough or coarse stimuli (e.g., burlap material, plastic mesh) under both active (e.g., Major, 1985; Ripin & Lazarsfeld, 1937) and passive touch conditions (Essick, James & McGlone, 1999; Essick et al., 2010) perhaps because smooth stimuli engender less friction (see Essick et al., 2010). It is less clear what makes some tactile vibrations feel more pleasant than others. Koskinen et al. (2008) found individual differences in pleasantness ratings of vibrations; whereas some individuals preferred strong vibrations, others preferred weaker vibrations. In the current study, we used a set of sine wave vibrations that varied in frequency (from 10–100Hz, i.e., from a slow flutter to a fast buzz), but were equivalent in intensity. During pilot testing, the majority of participants (8/10) rated the higher frequency vibrations (from 60-100Hz) as more pleasant than the lower frequency vibrations (form 10-50Hz), but we also found individual differences; 2/10 participants preferred the low frequency vibrations. Given that affective appraisals of vibrations may be subjective and vary between individuals, we used a mixed within/between subjects design. Participants completed two tactile tasks, one involving pleasantness rating and one involving discrimination, before and after completing a version of the Navon task designed to prime either a global, local, or no processing preference (by encouraging attention to the global, local or both aspects of a series of Navon stimuli). We expected processing style to impact on touch perception in two ways. Given the link between global processing and positive affect, global processing was expected to increase pleasantness ratings. Due to a heightened focus on details, local processing was expected to improve tactile discrimination.

According to Forster and Dannenberg’s (2010) GLOMO^{sys} model, activation of the same processing system through two different modalities should increase its accessibility and observed carry-over effects should be enhanced. In line with this idea, Forster (2011) reported that when participants processed globally or locally in more than one sensory modality, carry-over effects to a subsequent task involving a third sensory modality were increased. Therefore, we also investigated whether the local versus global nature of the pleasantness rating and discrimination tasks would result in additive carry-over effects. Although neither task involved a spatial component, the discrimination task involved attention to detail and the detection of differences, which are associated with local processing (see Forster & Dannenberg, 2010). Pleasantness rating, on the other hand, may have activated the global processing system, by increasing attention to positive affective experience. Although we expected some of our tactile vibrations to be rated as more pleasant than others, during pilot testing and our main experiment, average ratings for both the low and high frequency vibrations were above 0 on the scale from 100 (100% unpleasant) to 100 (100% pleasant), suggesting that they were perceived to be more pleasant than unpleasant.

Therefore, we expected stronger global/local carry-over effects when participants processed globally/locally in both the visual and the tactile modality. More specifically, we predicted that pleasantness ratings of the tactile vibrations would be lowest for participants who had a double dose of local processing prior to the pleasantness rating task (i.e., who attended locally during the Navon task and completed the tactile discrimination task before the pleasantness rating task). We predicted that discrimination would be poorest for participants who had a double dose of global processing prior to the discrimination task (i.e., who attended globally during the Navon task and completed the pleasantness rating task before the discrimination task).

Finally, following Forster's (2011) report of global versus local processing in the tactile modality affecting subsequent visual processing and arguments that a common perceptual mechanism determines processing level across modalities (Bouvet et al., 2011; Ivry & Robertson, 1998) we investigated whether there was a tactile-visual carry-over effect in our control group. This group were required to attend both the global and local features during the Navon task, which allowed us to measure the extent of global precedence (i.e., the degree to which they were quicker to detect targets appearing at the global, compared to local level). We expected to see reduced global precedence in participants who completed the tactile discrimination (i.e., local) task prior to the Navon task, compared to those who completed the pleasantness rating (i.e., global) task prior to the Navon task.

Method

Participants

An advertisement for participants with normal or corrected to normal vision, without any impairment in the feeling/sensation of their hands, was placed on the University of Manchester research volunteering website. The final sample consisted of ninety participants (64 female, aged between 18 and 53, *M* age = 21.87, *SD* = 4.75).

Study Design and Procedure

A mixed 3(group: global, local, control; *n* = 30 in each group) x 2(time: before and after the Navon task) x 2(tactile task order: pleasantness rating task first, discrimination task first) design was employed, with tactile task performance (pleasantness ratings, discrimination task accuracy or discrimination task false alarm rates) as the dependent variable. Figure 2 illustrates the study design and procedure. Participants attended one, hour long testing session. Upon arrival, a computer program was used to allocate participants to the global, local or control, and tactile task order group based on their participant number. In the global and local groups, there were an equal number of participants in each tactile task order group (n = 15). Due to an error in the computer program, in the control group, 14 participants completed the pleasantness rating task first, and 16 completed the discrimination task first. Participants completed a questionnaire measure of mood, then two tactile tasks (involving pleasantness rating or discrimination), before and after a version of the Navon task, designed to encourage a focus on the global, local or both aspects of the Navon stimuli.

INSERT FIGURE 2 ABOUT HERE

Questionnaire Measures

To control for the effect of pre-existing mood and to investigate whether either group showed a change in mood from before to after the Navon task, participants completed a state version of the Positive and Negative Affect Schedule (PANAS, Watson, Clark & Tellegen, 1988) at the beginning and end of the testing session. The PANAS consists of a list of ten positive and ten negative feelings and emotions (e.g., active, determined, excited, afraid, distressed, and irritable). Participants were instructed to rate the extent to which they were currently feeling each emotion, on a scale from 1 (very slightly or not at all) to 5 (extremely). Scores on the positive affect (PA) and negative affect (NA) subscales range from ten to fifty, with high scores indicating high experience of PA/NA. The PANAS has good construct validity and reliability (Watson et al., 1988; Crawford & Henry, 2004). Scores on each scale were compared before (time 1; T1) and after (time 2; T2) the Navon task and T1 scores were included as covariates in the main analyses to control for baseline mood.

Tactile Tasks

Materials. Participants were seated approximately 60cm in front of a computer monitor, which delivered the task instructions and listened to white noise throughout both tactile tasks to mask the sound of the vibrations. Tactile vibrations were presented using a bone conductor (with a 1.6cm × 2.4cm vibrating surface, Oticon Limited, B/C 2-PIN) that was attached to participants' left dorsal forearm (~5cm distal to the elbow), using a double sided adhesive pad. Tactile vibrations were produced by sending amplified sound files, controlled by E-Prime software (Psychology Software Tools Inc., Pittsburgh, PA, USA), to the bone conductor. A set of eleven, 500ms sine wave vibrations, ranging from 10-100 Hz were used in the pleasantness and discrimination tasks. To eliminate vision of the body and control for gaze direction, which are known to affect touch perception (e.g., Harris, Arabzadeh, Moore & Clifford, 2007; Mirams, Poliakoff, Brown & Lloyd, 2010), the experimenter covered the participant's left hand and arm with a black sheet before starting the tactile tasks and participants were instructed to look towards a central fixation cross on the computer monitor throughout the experiment.

Pilot testing. To ensure that the set of vibrations felt approximately equivalent in intensity (the higher the frequency, the higher the perceived intensity), in a pilot study, a separate group of ten participants completed an intensity matching task. Pairs of vibrations were presented, starting with the 10Hz vibration paired with the 100Hz vibration and participants were asked to decide whether the second vibration felt weaker, stronger or the same strength as the first vibration. The strength of the lower frequency vibration was increased until it felt the same strength as the 100Hz vibration. The procedure was repeated for each of the remaining lower frequency vibrations. The average increase in decibels necessary for each vibration to feel equivalent in intensity to the 100Hz vibration (i.e., elicit a “same” response) was then calculated and these set strengths were used in both tactile tasks.

To ensure that the set of vibrations elicited a range of pleasantness ratings, the same ten participants rated each of the intensity matched vibrations for pleasantness on a scale from -100 (100% unpleasant) to 100 (100% pleasant). On average, the higher frequency vibrations (60-100Hz) were rated as more pleasant (*M* pleasantness rating = 17.72) than the low frequency vibrations (10-50Hz, *M* pleasantness rating = 6.19).

Pleasantness rating task. Participants were initially presented with the 20, 40, 60, 80 and 100Hz vibrations to demonstrate the difference in frequency. They were then presented with each of the ten (10-100Hz) vibrations, one at a time, in a random order, and asked to rate them for pleasantness on a scale from -100 (100% unpleasant) to 100 (100% pleasant), by entering a numerical value using the computer keyboard. There was no time limit to respond and the next trial started after participants’ input their response. Participants completed four practice trials, followed by eighty experimental trials, divided into two blocks (each frequency vibration was rated eight times). This task took approximately seven minutes to complete.

Discrimination task. Participants were initially presented with the 20, 40, 60, 80 and 100Hz vibrations to demonstrate the difference in frequency. Participants were then presented with a pair of vibrations and asked “was that pair of vibrations different or the same?” and responded by typing 1 (different) or 2 (the same) using the computer keyboard. The question was worded this way, instead of “was that pair of vibrations the same or different?” and with number 1 for “different”, to encourage a focus on differences, rather than similarities between stimuli and so encourage local processing (see Forster & Dannenberg, 2010). The frequency difference in each pair was set to make four conditions: same, easy, medium and difficult (see

Table one). Vibration order (vibration one first, vibration two first) was randomised. When participants compare the frequency of two serially presented vibrations, they must rely on a memory of the first vibration, in order to compare it to the second (Harris, Harris & Diamond, 2001). Evidence suggests that when participants make a difficult comparison between a pair of vibrations (with a small difference in frequency), they rely on tactile memory traces of the first vibration, which diminish after 2 seconds (e.g., Harris et al., 2001), therefore we chose an inter stimulus interval (ISI) of 1500ms. The timing of the trial sequence was as follows: vibration 1 (500ms); ISI (1500ms); vibration 2 (500ms); response screen (until response). The next trial began after the participant input their response. Participants initially completed five practice trials, followed by forty eight experimental trials, divided into two blocks. This task took approximately seven minutes to complete.

INSERT TABLE 1 ABOUT HERE

All participants completed both tactile tasks twice (before and after the Navon task), however tactile task order (pleasantness rating task first/discrimination task first) was counterbalanced between participants (see Figure 2).

Navon Task Materials, Design and Procedure

Navon task design and procedure followed Forster (2011). E-prime software was used to present stimuli and collect responses. A series of global letters (2.5 x 2.5cm) made up of local letters (0.5 x 0.5cm) were used as the stimuli and participants were seated 60cm in front of the computer monitor. Each horizontal and vertical line making up a global letter consisted of five closely spaced local letters. On each trial, participants were presented with a fixation cross in the centre of the screen for 500ms, followed by one of eight global composite letters: An F made of Hs, an F made of Ls, a H made of Fs, a H made of Ts, an L made of Fs, an L made of Ts, a T made of Hs, and a T made of Ls. Participants were instructed to press the L key if the stimulus contained the letter L, or to press the H key if the stimulus contained the letter H. The stimulus always contained the letter L, or H and participants were instructed to respond as quickly as possible and to look towards the central fixation cross throughout the task. Figure 1 illustrates the Navon task trial procedure.

Participants in the global group were informed that they would be presented with a series of visual stimuli, consisting of a large letters, made from a number of smaller letters. For this group, L’s and H’s only ever appeared as the global element of the stimuli, therefore, this group were presented with one of the following four stimuli on each trial: a H made of Fs, a H made of Ts, an L made of Fs or an L made of Ts. Participants in the local group were informed that they would be presented with a series of visual stimuli, consisting of small letters, that make the shape of a large letter. For this group, Ls and Hs only ever appeared as the local element of the stimuli, therefore, this group were presented with one of the following four stimuli on each trial: an F made of Hs, an F made of Ls, a T made of Hs, or a T made of Ls. Participants in the control group were informed that they would be presented with a series of visual stimuli consisting of letters. They were instructed to press the L key if either the overall shape of the stimulus, or the smaller letter, was L, or the H key if either the overall shape of the stimulus, or the smaller letter, was H. Participants in this group were presented with all eight Navon stimuli (containing both global and local targets). Participants in each group completed 96 trials divided into two blocks. This task took approximately six minutes to complete.

INSERT FIGURE 1 ABOUT HERE

Results

T1 and T2 NA scores were not normally distributed (positively skewed) and remained so after attempts to transform the data, therefore, these data were analysed using non-parametric tests and T1 NA scores could not be included as a covariates in the main analyses as planned.

A MANOVA showed that participant groups did not differ in age, $F(2,85) = .59$, $MSE = 24.35$, $p = .56$, T1 PA, $F(2,85) = 1.89$, $MSE = 46.85$, $p = .16$, or T2 PA scores, $F(2,85) = 1.98$, $MSE = 51.60$, $p = .14$. A 3(group: global, local, control) x 2 (time: before Navon task, after Navon task) mixed design ANOVA, with PA scores as the dependent variable, showed a main effect of time, $F(1,85) = 30.84$, $MSE = 17.33$, $p < .001$, $d = .84$, but no effect of group ($p = .10$) and no group x time interaction ($p = .94$). For all participants, PA was higher at T1 ($M = 27.23$) than T2 ($M = 23.74$). Independent samples Kruskall-Wallis tests showed that processing groups did not differ in T1 or T2 NA scores (p's $\geq .31$) and separate Wilcoxon tests showed that NA scores were lower at T2 than T1 for each group (p's $\leq .04$). Therefore, participants reported a reduction in both positive and negative mood from the beginning, to the end of the experiment.

To investigate whether processing style and task order affected pleasantness ratings, average pleasantness ratings were analysed in a 3(group: global, local, control) x 2(time: before Navon task, after Navon task) x 2 (task order: pleasantness rating task first, discrimination task first) x 2(vibration frequency: high, low) mixed design ANOVA without, then with T1 PA scores included as a covariate. A group x time x task order interaction was expected, with higher pleasantness ratings in the global group after the Navon task, particularly for participants who did the pleasantness rating task first.

Figure 3 shows average pleasantness ratings for the high and low frequency vibrations at T1 and T2 for each group. There was a main effect of frequency, $F(1,84) = 17.55$, $MSE = 982.37$, $p < .001$, $d = .44$; pleasantness ratings were higher for the high ($M = 20.73$) than for the low ($M = 6.88$) frequency vibrations. There was also a main effect of tactile task order $F(1,84) = 9.67$, $MSE = 1569.56$, $p = .003$, $d = .34$; participants who did the pleasantness rating task first rated the vibrations as more pleasant ($M = 20.31$) than participants who did the pleasantness rating task after the discrimination task ($M = 7.31$). There was also a tendency towards a main effect of time, *F*(1,84) = 3.57, *MSE* = 119.09, *p* =.06, *d* = .20. Overall, pleasantness ratings tended to be higher at T2 (*M* = 14.90), than T1 (*M* = 12.72), which suggests that the effect of pleasantness/discrimination task order was not due to boredom or fatigue (if this was the case, pleasantness ratings would be lower at T2). The main effect of group was not significant (*p* = .50), however, there was a significant interaction between time, frequency and group, *F*(2,84) = 3.59, *p* = .03. These findings remained the same with T1 PA scores included as a covariate. To follow up this interaction, three separate 2(frequency) x 2(time) mixed design ANOVAs were conducted for each group.

For the global group, there were significant main effects of frequency, *F*(1,29) = 13.77, *MSE* = 988.59, *p* = .001, *d* = .69 and time, *F*(1,29) = 4.99, *MSE* = 183.36, *p* = .03, *d* = .42 and a tendency towards a time x frequency interaction, *F*(1,29) = 4.35, *MSE* = 60.34, *p* = .05. The increase in pleasantness rating from T1 to T2 was significant for the high, *t*(29) = 2.46, *p* = .02, *d* = .64, but not the low frequency vibrations, *t*(29) = 1.23, *p* = .23, *d* = .32. For the local group, there was no effect of frequency, *F*(1,29) = 2.47, *MSE* = 1193.19, *p* = .13, *d* = .29, or time, *F*(1,29) = .03, *MSE* = 68.99, *p* = .87, *d* = .03, and no frequency x time interaction, *F*(1,29) = 1.78, *MSE* = 43.79. *p* = .19. For the control group, there was a significant effect of frequency, *F*(1,29) = 4.53, *MSE* = 688.31, *p* = .04, *d* = .40 but no effect of time, *F*(1,29) = 2.46, *MSE* = 991.85, *p* = .13, *d* = .30 and no frequency x time interaction, *F*(1,29) = 2.18, *MSE* = 91.27. *p* = .15.

To investigate the possibility that the Navon task had a short-lived effect, which dissipated over the course of the pleasantness rating task, the above analyses were repeated looking only at performance during the first block of the pleasantness rating task. The results remained the same, plus the time x frequency interaction in the global group became significant, *F*(1,29) = 9.95, *MSE* = 103.61, *p* = .01. To summarise, the global group rated the high frequency vibrations as more pleasant after the Navon task. The local and control group showed no change in pleasantness ratings from before to after the Navon task.

INSERT FIGURE 3 ABOUT HERE

To investigate whether processing style affected participants' ability to discriminate between the different frequency vibrations, change in average accuracy over all conditions (percentage of correct responses T2 – percentage of correct responses T1) was analysed in a 3(processing group: global, local, control) x 2 (task order: pleasantness rating task first, discrimination task first) between subjects ANOVA without, then with T1 PA scores included as a covariate. Change scores were analysed, rather than including time as a factor, to increase statistical power. A group x task order interaction was expected, with higher change scores (reflecting an increase in accuracy from T1 to T2) in the local group, particularly in participants who did the discrimination task first.

Table two shows average accuracy in the easy, medium, difficult and same conditions of the discrimination task before and after the Navon task and overall change in accuracy from before to after the Navon task in each group. All groups showed a similar increase in accuracy, around 2%. There was no effect of group, $F(2,84) = .04$, $MSE = 157.12$, $p = .96$, or task order, $F(1,84) = 2.50$, $MSE = 157.12$, $p = .12$ and no group x task order interaction, $F(2,84) = .33$, $MSE = 157.12$, $p = .72$. These findings remained the same with T1 PA scores included as a covariate, and when the above analyses were repeated looking only at performance during the first block of the discrimination task.[1]

Next, to investigate whether processing style affected the number of false alarms (i.e., incorrect "different" responses made in the same condition of the discrimination task), false alarm rates [number of "different" responses + 0.5 x (number of "different" responses + number of "same" responses +1)] were calculated and change scores (FA rate at T2 – FA rate at T1) were analysed in a 3(group: global, local, control) x 2(task order: pleasantness rating task first, discrimination task first) between subjects ANOVA, without, then with T1 PA scores included as a covariate. A group x task order interaction was expected, with lower change scores (reflecting a reduction in false alarm rates from T1 to T2) in the local group, particularly in participants who did the discrimination task first. There was no group x task order interaction, $F(1,84) = .81$, $MSE = .03$, $p = .45$, no effect of group, $F(1,84) = .84$, $MSE = .03$, $p = .44$ and no effect of task order, $F(1,84) = .32$, $MSE = .03$, $p = .57$. To summarise, change in discrimination task performance from before to after the Navon task did not differ between the local, global or control groups.

INSERT TABLE 2 ABOUT HERE

To investigate whether the global versus local nature of the pleasantness and discrimination tasks had a carry-over effect to Navon task performance in the control group (for whom targets appeared at both the global and local level), difference scores (average reaction times to local Navon targets – average reaction times to global Navon targets) were compared between participants who did the discrimination task immediately prior to the Navon task and participants who did the pleasantness rating task immediately prior to the Navon task in a univariate ANOVA, with T1 PA scores included as a covariate. Following Forster (2011) reaction times for incorrect responses (1.84% of trials) were excluded, as were reaction times over 3 standard deviations from the mean for each stimulus (1.36% of trials). Difference scores were expected to be higher (indicating a stronger global bias) in participants who did the pleasantness rating task immediately prior to the Navon task.

In the control group, there was a tendency towards an effect of pleasantness/discrimination task order, $F(1,26) = 3.22$, $MSE = 8975.01$, $p = .08$, $d = .69$ on Navon task difference scores. Participants who did the pleasantness rating task immediately prior to the Navon task showed the usual global precedence effect, i.e., reaction times tended to be faster to global ($M = 713.65$) than to local targets ($M = 771.00$), $t(15) = 1.95$, $p = .07$, d

= .71. Participants who did the discrimination task immediately prior to the Navon task, however, lacked the global precedence effect. Their reaction times to global targets (*M* = 677.26) were no faster than reaction times to local targets (*M* = 678.41), *t*(13) = .07, *p* = .95, *d* = .03. Between-group comparisons showed that participants who did the tactile discrimination task immediately prior to the Navon task did not have significantly faster reaction times to local targets compared to those who did the pleasantness rating task immediately prior to the Navon task, *t*(28) = 1.59, *p* = .12, however, nor was there a between-group difference in reaction times to global targets, *t*(28) = .95, *p* = .35.

Discussion

Our aim was to investigate the effect of global versus local attention on the subsequent perception of tactile vibrations, under passive touch conditions. Based on Forster's (2011) previous findings of global/local carry-over effects under active touch conditions (e.g., Forster, 2011) and links between positive emotion and global processing (e.g., Gasper & Clore, 2002), we expected prior global processing in the visual modality to increase the pleasantness of passive touch. In line with this hypothesis, attending to the global features of a series of Navon stimuli increased pleasantness ratings of the high frequency tactile vibrations. By encouraging a focus on details, we expected local processing to improve tactile discrimination, however, local processing during the Navon task did not improve frequency discrimination of the same tactile vibrations.

McCabe et al. (1998) found that expectations have a top-down influence on affective touch (pleasantness ratings of skin cream). We found that global versus local processing also has a top-down influence on affective touch. This finding is consistent with the suggestion that global processing promotes positive emotion (Srinivasan & Gupta, 2011; Srinivasan & Hanif, 2010). Participants in the global group did not show a change in self-reported emotion from T1 (the beginning of the testing session) to T2 (the end of the testing session). Although it is possible that transient changes in mood were missed, as participants did not rate their mood immediately after the Navon task. It is likely that more intensive attentional training, over a longer period of time, would be necessary to change self-reported mood. Unexpectedly, global processing during the Navon task only increased pleasantness ratings for the high (but not the low) frequency vibrations, which participants rated as more pleasant at baseline. After the global Navon task there was only a small, non-significant increase in pleasantness ratings for the low frequency vibrations (Cohen's *d* = .32). It could be that global processing only increases the pleasantness of tactile stimuli that are distinctly pleasant (as opposed to neutral or unpleasant). On average, the low frequency vibrations were rated as pleasant (rather than unpleasant), but with an average rating of 11.78 on the scale from -100 (100% unpleasant) – 100 (100% pleasant), were close to neutral. This possibility could be explored in future by comparing the effect of global/local processing on the pleasantness of other tactile stimuli with a more distinct difference in pleasantness, known to be characteristically pleasant/unpleasant, such as cosmetic brushes/velcro (Essick et al., 2010).

Our finding that global processing affects emotional responses to touch could have practical applications. For example, real-world variables, such as the colour of packaging could be manipulated to trigger global processing (see Friedman & Forster, 2010; and Forster & Dannenberg, 2010, p182) in order to increase consumer's enjoyment of "tactile" products such as skin creams. According to the GLOMOsys model (Forster & Dannenberg, 2010), global-local carry-over effects should occur across sensory modalities, therefore future studies could investigate whether priming global/local processing in the auditory, or olfactory senses (e.g., by asking participants to rate the pleasantness of a piece of music/smell, or distinguish the component parts), also affects the subsequent pleasantness of touch. Our finding of higher pleasantness ratings for high, compared to low frequency vibrations, particularly under conditions of global attention, could also inform the design of haptic feedback in electronic devices such as mobile phones and games consoles.

Forster (2011) found that global and local processing in the visual modality influenced whether participants subsequently touched the whole versus the details of an object (i.e., active touch). We have shown that global processing also affects the subsequent perception of passively received touch which was the same for all participants. This finding is consistent with our previous findings that different attentional states affect passive touch perception (e.g., Mirams et al., 2011; Mirams et al., 2013) and with Forster and Dannenberg's (2010) GLOMO^{sys} model, which states that when one processing system is active, it remains active and can affect performance on other tasks. This finding also provides further evidence for the theory that a common perceptual mechanism determines processing level across modalities (Bouvet et al., 2011; Ivry & Robertson, 1998).

Contrary to our hypothesis, local processing during the Navon task did not improve tactile discrimination ability, and nor did it reduce pleasantness ratings. This could suggest that our "local" version of the Navon task did not induce a local processing bias which was sufficiently strong to have a carry-over effect to the tactile tasks. Alternatively, carry-over effects of global-local processing might depend on the nature of the subsequent task. It is possible that prior local processing only affects discrimination ability under active touch conditions. Furthermore, although the discrimination task involved paying attention to the details (i.e., the frequency) of the vibrations to detect differences, it did not involve a spatial component. Although Forster (2011) reported carry-over effects of local processing on non-spatial auditory and gustatory tasks, carry-over effects may be more likely on a spatial task. We found an effect of global processing on pleasantness rating, however, despite the fact that this task was not spatial.

Another possible reason why local processing did not affect tactile discrimination could be that all participants were "optimally local" during the discrimination task. According to Forster and Dannenberg's (2010) GLOMO^{sys} model, people will switch to an alternative processing style if their current mode of processing is no longer sufficient for the task at hand. All participants may have adopted a local processing style during the tactile discrimination task, regardless of whether they had previously focused globally or locally[2].

The lack of local processing carry-over effects could also be related to hemispheric differences; previous research suggests a left hemisphere advantage for local processing and a right hemisphere advantage for global processing (see Van Kleek, 1989 for a review). In the current study, tactile vibrations were presented to the left forearm, which is mainly represented in the right hemisphere. It is possible therefore, that local processing would have been more likely to affect the perception of touch presented to the right arm.

According to the GLOMO^{sys} model, activating the same processing system through two different modalities should increase its accessibility (Forster, 2011). Indeed, Forster (2011) found that focusing globally/locally during an auditory plus a gustatory task enhanced carry-over effects to a third, visual task. Therefore, in the current study, we also investigated whether processing globally/locally in both the visual and tactile modalities would increase carry-over effects. For example, we predicted that discrimination ability after the Navon task would be lowest in participants in the global group who did the pleasantness rating task first (i.e., who had a double dose of global processing). However, we did not find any evidence to support this hypothesis; the expected interactions between group, time, and task order for pleasantness ratings and between group and task order for the discrimination task change scores, were not significant. This may have been because our tactile tasks did not involve a spatial component, which may have made it more likely to see multiplicative carry-over effects.

Consistent with the idea that the two tactile tasks involved different processing systems, however, we found an effect of tactile task order on pleasantness ratings[2]. Pleasantness ratings tended to be lower in participants who did the more “global” pleasantness rating task after the “local” discrimination task, compared to those who rated the vibrations for pleasantness first. We do not think that the effect of tactile task order was due to boredom or fatigue, because overall, pleasantness ratings were higher after, compared to before the Navon task. This order effect may have occurred because local processing promotes negative emotion (e.g., Srinivasan & Gupta, 2011; Srinivasan & Hanif, 2010), or because adopting an incongruent, local processing style during the discrimination task disrupted performance on the more global pleasantness rating task (c.f. Forster, 2011). Furthermore, we found some evidence of tactile-visual carry-over effects in the control group (who were required to respond to both global and local Navon targets). Those who did the tactile discrimination (rather than the pleasantness rating) task immediately prior to the Navon task tended to show reduced global precedence (i.e., were no faster to respond to global, than local Navon targets), which is consistent with Forster’s (2011) finding that local active touch reduces global precedence during the Kimchi-Palmer and Navon tasks. However, these findings should be interpreted with caution, given that the primary purpose of the tactile tasks was to measure the effects of a global versus local attentional state on affective and discriminative touch perception, rather than to induce global or local processing. In addition, participants who did the tactile discrimination (rather than the pleasantness rating) task immediately prior to the Navon task did not have significantly faster reaction times to local targets/slower reaction times to global targets. To investigate tactile-visual carry-over effects of global/local processing, it would be more appropriate to encourage attention to the whole, versus the details during a spatial tactile task, with an increased sample size.

We have found that prior global processing in the visual modality affects the subsequent pleasantness of passive touch. We are currently investigating whether global/local processing impacts on affective and discriminative touch perception using spatial tactile stimuli under active touch conditions. It has been suggested that broad versus narrow perceptual attention could have carry-over effects to higher level cognitive processes, such as self/other evaluations and comparisons (Forster, 2011). Next, we are planning to investigate whether tactile global/local processing affects evaluations of self-healthiness and judgments of self-healthiness against others.

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Footnotes

1 To investigate the possibility that local processing during the Navon task affected tactile discrimination in the difficult condition, and in participants who did the tactile discrimination task immediately after the Navon task, we conducted separate 3(Navon task group: global, local, control) between subjects ANOVAs for each condition order group, with change in average accuracy in the difficult condition as the dependent variable. Average accuracy on the difficult condition did not differ between Navon task groups for the participants who did the discrimination task first (immediately after the Navon task, $F(2,43) = 1.71$, $p = .19$) or for participants who did the discrimination task second (after the pleasantness rating task, $F(1,41, = 2.04$, $p = .14$).

2 Although there was a significant main effect of tactile task order when group was included as a factor ($p = .003$), the effect of tactile task order did not reach significance when data from the global ($p = .07$) local ($p = .06$) and control groups ($p = .13$) were analysed separately.

3 A limitation of our discrimination task was that it included more “different” than “same” trials, which may have biased participants towards a “different” response, adversely

affecting accuracy. In future research, the task could be altered to include an equal number of "different" and "same" trials to reduce bias.

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Appendices

Tables

Table 1

Vibration pairs and conditions in the tactile discrimination task

Pair number:	Vibration one	Vibration two	Condition	Number of trials
1	20Hz	20Hz	same	x 6
2	20Hz	40Hz	difficult	x 6
3	20Hz	50Hz	medium	x 6
4	20Hz	60Hz	easy	x 6
5	40Hz	40Hz	same	x 6
6	40Hz	80Hz	difficult	x 6
7	40Hz	100Hz	medium	x 6
8	40Hz	120Hz	easy	x 6

Note. The frequency difference in each condition was not the same for pairs 1-4 and pairs 5-8 in order to keep the Weber fraction constant; the same difference in frequency is not perceived as equal at all frequency levels. A 120Hz vibration was included to make pair 8 equivalent in difficulty to pair 4. The strength of the 120Hz vibration was lowered (-6db), to match it in intensity to the 100Hz vibration.

Table 2

Mean (and SD) percentage accuracy in each condition of the discrimination task before and after the Navon task.

Condition	*Global*		*Local*		*Control*	
	Before Navon	After Navon	Before Navon	After Navon	Before Navon	After Navon
Easy	74.17 (18.61)	78.06 (16.45)	73.06 (15.27)	76.67 (15.99)	77.78 (15.53)	73.89 (22.29)
Medium	61.67 (18.52)	65.83 (17.14)	65.00 (18.62)	66.11 (16.94)	60.28 (18.79)	66.94 (17.71)
Difficult	49.72 (17.16)	53.06 (19.75)	49.72 (17.16)	56.67 (17.97)	48.61 (17.66)	48.89 (19.66)
Same	81.67 (12.65)	79.17 (18.01)	76.67 (19.62)	76.39 (15.49)	76.94 (14.63)	80.83 (14.87)
Overall change in accuracy	2.22		2.57		1.74	

Note. This table shows averaged performance of the two tactile task order groups.

Figure Captions

Figure 1. Navon task trial procedure and example stimuli. Participants were asked to decide whether the stimulus contained the letter L or H. A: The target H appears as the global feature (presented during the global and neutral versions of the task). B: The target H appears as the local element (presented during the local and neutral versions of the task).

Figure 2. Illustration of the study design and procedure.

Figure 3. Average pleasantness ratings for the low and high frequency vibrations before (Time 1) and after (Time 2) the Navon task in each processing group. Error bars reflect + 1 standard error of the mean.