

Social and Emotional Touch between Romantic Partners is Affectively More Pleasant due to Finely Tuned Contact Interactions

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Abstract—Our daily observations tell us that the delivery of social sentiments and emotions differs between strangers and romantic partners. This work explores how relationship status influences our delivery and perception of social touches and emotions, by evaluating the physics of contact interactions. In a study with human participants, strangers and romantically involved touchers delivered emotional messages to receivers' forearms. Physical contact interactions were measured using a customized 3D tracking system. The results indicate that strangers and romantic receivers recognize emotional messages with similar accuracy, but with higher levels of valence and arousal between romantic partners. Further investigation into the contact interactions which underlie the higher levels of valence and arousal reveals that a toucher tunes their strategy with their romantic partner. For example, when stroking, romantic touchers use velocities preferential to C-tactile afferents, and maintain contact for longer durations with larger contact areas. Notwithstanding, while we show that relationship intimacy influences the deployment of touch strategies, such impact is relatively subtle compared to distinctions between gestures, emotional messages, and individual preferences.

Index Terms—Social touch, affective touch, emotion communication, romantic relationship

I. INTRODUCTION

In daily social interactions, we intuitively touch others to share our feelings and convey social intentions [1]–[3]. Such interpersonal touch plays an important role in maintaining our physical and emotional well-being as well as facilitating intimate bonds and social connections [4], [5]. Moreover, we consciously or unconsciously vary our ways of touching and our attitudes toward being touched when it comes to different people [6]–[13]. For example, a comforting caress delivered by one's partner might feel totally different when delivered by a stranger. In respecting personal space and following social etiquette, we do not usually touch a stranger in the same way as an intimate friend or family member.

As intimate touch is more prevalent and natural, many efforts have investigated social touch in close relationships, especially romantic couples [4], [12], [14]–[18]. Physiological, psychological, and brain responses collected from touch receivers indicate that touch delivered by a partner can lower one's heart rate and blood pressure, elicit more positive and pleasant affect, as well as induce brain responses related to pain and emotion regulation [4], [12]. In addition, physical touch behaviors have been observed [14]–[16] and verified as being intuitively understood [15]. Other efforts have evaluated touch delivery among strangers [1], [2], [12],

wherein receivers respond to less consistently and favorably [12]. Together, these studies illustrate that romantic social touch is indeed effective and beneficial to the physical and mental wellbeing of receivers. Indeed, the fact that the majority of prior studies explicitly consider relationship status implies its importance.

To better understand the role of relationship status, direct comparisons are needed between individuals with distinct types of social bonds. From online self-report studies, we see that when the strength of one's emotional bonds increase, the body regions permitted for social touch increase proportionally [6], [8]. Moreover, the frequency and desire to touch increase with interpersonal intimacy [10]. In terms of affective responses, touch from one's partner is reported to be more pleasant and comfortable than with less closely bonded individuals [8], [9], [11]. Similar results are also reported in human-subjects experiments, where partner touch elicits more pleasant responses [19]. When it comes to the communication of emotions, couples recognize a wider range than strangers, especially self-focused emotions [7].

The physical delivery of contact, as well, influences an emotion's recognition and affective charge. As skin contact is the primary interface for social touch, it has been widely reported that pleasantness, as well as neural responses of C-tactile (CT) afferents, follow an inverted U-shape curve relative to stroking velocity [20]. Such inspiration causes us to hypothesize that a romantically involved toucher might modulate her or his contact interactions to alter her or his receiver's perception. However, the physics of such contact changes has seldom been quantified, where velocities have been compared across relationship status for only the stroking gesture [13], and vibration of the toucher's finger has been analyzed between touching themselves or another person [21].

This work investigates the impact of relationship status in social touch by quantifying skin contact interactions. More specifically, experiments are conducted where emotional messages are delivered by touching a receiver's forearm. Responses from receivers are first compared among romantic couples and strangers. Measured skin contact is then correlated with perceptual performance. Finally, relationship status is evaluated relative to other contextual factors.

II. METHODS: EMOTION COMMUNICATION TASK

A. Participants

Five couples in romantic relationships were recruited (5 males, 5 females, age = 23.8 ± 5.0). Per couple, a stranger

participant was recruited separately and grouped with that couple, making five stranger participants in total (3 males, 2 females, age = 24.0 ± 4.4). The study was approved by the Institutional Review Board at the University of Virginia, and all participants granted consent to participate.

B. Experimental Setup

As shown in Fig. 1A, one toucher and one touch receiver were involved in the emotion communication task. Two participants sat at opposite sides of an opaque curtain to eliminate visual communication and were instructed to avoid verbal communication. A cushion was set on the toucher's side, where the receiver rested her or his left arm on and could not see the contact interaction delivered by the toucher. Touch instructions and perceptual questions were displayed to the toucher and receiver separately on two computer displays. Participants were instructed to use a mouse to interact with the experiment's user interface. A depth camera was aimed at the receiver's arm to capture hand-arm interactions.

C. Emotional Message Stimuli

As shown in Table 1, seven emotional messages were adopted from prior studies as instructions for touchers [1], [2], [7], [14], [18]. Those messages have been reported to be recognizable and preferable to communicate in social touch. In addition, three commonly used gestures [1], [2], [7], [14], [18] were selected per emotional message and provided to touchers. Gestures of holding and squeezing were combined as a single option due to similar hand poses and contact patterns. Similarly, hitting was added to the tapping option for the anger message to better fit its natural expression.

D. Experimental Procedures

For each group of three participants, including a couple and a stranger, four experimental sessions were designed. Two of the sessions were conducted by the couple, with their roles as toucher/receiver reversed between sessions. The other two sessions were conducted with the stranger as the receiver and either of the couple participants assigned as the toucher alternatively. Therefore, twenty sessions were completed in total, where ten romantically involved participants delivered contact to both their partner and the stranger. Participants were aware of who the other participant was before each session. Note that experimental sessions between couples were conducted before strangers to moderate the reluctance of physical contact between strangers, which might have an influence on the toucher's contact performance. Within each session, seven emotional messages were conveyed with each message repeated six times. The forty-two message instructions were provided to the toucher in a random order.

Per experimental trial, one emotional message was displayed to the toucher with three corresponding gestures listed with a random order. The toucher selected only one gesture by clicking it and then expressed the message by touching the receiver's forearm using the selected gesture. No constraints were given regarding how to deliver a gesture. Any contact patterns the toucher considered as that gesture could be used. For the same message across different trials, touchers were also free to choose either the same gesture or different ones. After contact was delivered, touchers clicked another button to inform the receiver to answer the perceptual questions. The first question was to identify the emotional

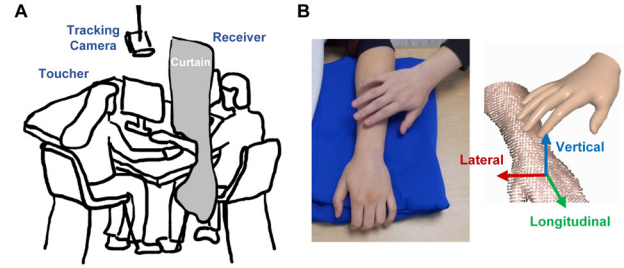


Figure 1. (A) Experimental setup. Touchers and receivers were separated by an opaque curtain with no verbal or visual communication. Instructions and questions were displayed on the screen for participants to interact. A depth camera tracked contact interactions. (B) One frame captured by the depth camera and the resultant 3D visualization of tracked contact.

TABLE I. EMOTIONAL MESSAGES AND ASSOCIATED GESTURES

Message	Gestures		
Anger (Ag)	Hit/Tap	Hold/Squeeze	Shake
Happiness (H)	Shake	Tap	Stroke
Fear (F)	Hold/Squeeze	Shake	Tap
Gratitude (G)	Hold/Squeeze	Shake	Tap
Sympathy (S)	Stroke	Tap	Hold/Squeeze
Attention (At)	Tap	Shake	Hold/Squeeze
Calm (C)	Hold/Squeeze	Stroke	Tap

message they recognized from the contact. It was a seven-alternative forced choice question with the same seven messages provided to touchers. The next two questions rated perceived levels of valence and arousal. Both affective ratings were collected using the Self-Assessment Manikin (SAM) with nine levels [22]. Valence represents pleasantness, which ranges from least to most pleasant. Arousal represents emotional intensity, which ranges from least to most intense. After all questions were answered, the receiver clicked a button to inform the toucher to proceed to the next trial. Participants could fully control the pace of the experiments.

E. Measurements of Hand-Arm Contact

As classic tactile sensor would barrier the direct contact between the toucher and receiver [23], we decided to quantify contact interactions using a 3D visual tracking system. The 3D shape and movements of the toucher's hand and touch receiver's forearm were tracked using the Azure Kinect depth camera (30 Hz, Microsoft, USA). Contact interactions between the hand and forearm were quantified using a customized point-cloud based algorithm [24]. Six time-series contact attributes were derived when hand-arm contact was detected, which includes absolute spatial contact velocity, contact area, indentation depth, three orthogonal velocity components in longitudinal, lateral, and vertical directions (Fig. 1B) [24], [25]. Per experimental trial, the mean value of the six time-series contact attributes was used to derive scalar measurements. In addition, the overall contact duration of one trial was collected as the seventh contact attribute.

III. METHODS: DATA ANALYSIS

Analyses were conducted to investigate the impact of relationship status on social touch in terms of emotional perception, contact delivery, and their correlation. In addition, the impact caused by relationship status was further compared with that of other factors in the context of social touch, i.e.,

gesture, emotional message, and individual toucher. Note that seven of 840 trials were removed due to poor tracking quality.

A. Impact on Emotional Perception

The recognition accuracy of all communicated emotional messages were first counted in the format of separate confusion matrices for couples and strangers. Mann–Whitney U tests [26] were applied to compare the participants’ recognition accuracies of each message between couples and strangers. The total number of trials each emotional message was recognized by receivers was also counted and compared.

Affective ratings of valence and arousal reported by receivers were further compared between couples and strangers. The ratings were first grouped by delivered gestures and recognized emotional messages. Since receivers were different participants between the touch communication of couples and strangers, Mann–Whitney U tests were conducted to compare ratings between the two relationship statuses. Cohen’s D effect sizes [27] were then calculated and reported for significantly different pairs. With multiple tests implemented, the Benjamini-Hochberg method [28] was applied for post-hoc correction.

B. Impact on Contact Delivery

The impact from relationship status on contact delivery may be twofold: gesture preference and contact attributes. For gestures, the total number of trials that each gesture was used by couples and strangers were counted and compared. The distribution of each contact attribute was then compared between couples and strangers. Since the same participant delivered contact to both the partner and the stranger, linear mixed effects model [29] was used for significance tests with relationship being the fixed effect and participants’ intercept being the random effect. F-tests and p-values for the fixed-effect term using Satterthwaite degrees of freedom were reported [29]. The partial η^2 effect sizes [30] were calculated for significantly different pairs. Benjamini-Hochberg method was used for post-hoc multiple testing correction.

C. Impact on Correlations between Contact Attributes and Affective Ratings

As widely reported by neuropsychology studies, an inverted-U shape pattern is observed between the pleasantness sensation and log-transformed stroking velocities. Therefore, linear mixed effects model was used for both linear and quadratic regressions to characterize correlations between contact attributes and affective ratings with all gestures aggregated. Contact attribute was treated as the fixed effect, while both touchers and receivers were treated as random intercepts. F-tests for the fixed-effect term using Satterthwaite degrees of freedom and the partial η^2 effect sizes were reported. Only combinations with notable differences between couples and strangers are elaborated upon in Results.

Similar analyses were further conducted for the stroking gesture, where the distribution of contact attributes and valence ratings were examined. The linear mixed effects model was applied to compare contact attributes between couples and strangers with Benjamini-Hochberg post-hoc correction. Only attributes with notable differences between couples and strangers were reported.

D. Comparing the Impact of Relationship with Other Factors in Social Touch

We compared the variation of contact attributes caused by relationship status with that of the other three contextual factors: gestures, emotional messages, and individual touchers. The metric *var* was developed to quantify the variation caused by a certain factor. In this case, the other three factors should remain the same. For example, *var* of relationship status represents the contact variation caused by switching from touching the partner to the stranger, when the same toucher used the same gesture to express the same emotional message. For another example of gesture, *var* represents the contact variation caused by switching among different gestures when the same toucher expressed the same emotional message under the same relationship status.

Detailed derivation of this metric is explained as follows using the factor of gesture as an example. $N_c = 140$ conditions were first identified, which came from all combinations of the other three factors, i.e., seven messages multiplied by ten touchers and two relationship statuses. Since contact was quantified as seven-dimensional contact attributes, its variance is defined as a covariance matrix. To obtain a scalar metric for comparison, the contact variation was formulated here as the trace, i.e., the sum of eigenvalues, of the covariance matrix of multi-dimensional contact attributes. Therefore, for each condition c_i , contact variation caused by changing gestures was written as $var^{c_i} = \text{tr}(\text{Cov}(\mathbf{att}^{c_i}))$. To better calculate eigenvalues of the covariance matrix, the dimension of contact attributes was reduced using principal component analysis (PCA) by taking only the first two principal components (PCs), so that $\mathbf{att}^{c_i} = [\mathbf{PC}_1^{c_i}, \mathbf{PC}_2^{c_i}]^T$. The number of data points in $\mathbf{att}^{c_i}$ equals to the number of gestures used in condition c_i . Per gesture, $\mathbf{PC}_1$, $\mathbf{PC}_2$ were derived as the mean value over all trials under that gesture. Note that conditions with only one gesture were removed since there was no variation. Therefore, *var* of gesture was finally derived as the mean of $N_{\text{valid}} = 67$ valid conditions: $var = \sum_{c_i}^{N_{\text{valid}}} var^{c_i} / N_{\text{valid}}$.

The *var* of the other three factors was calculated following the same procedure. The total number of conditions N_c was 80, 56, and 280 for the emotional message, individual toucher, and relationship status, respectively. After removing conditions with only one record, the number of valid conditions N_{valid} was 69, 36, and 88 for the three factors. In order to compare the contact variation introduced by the four factors, Mann–Whitney U tests were conducted with Benjamini-Hochberg post-hoc correction.

IV. RESULTS

A. Couples Perceive Higher Valence and Arousal

Among the seven emotional messages communicated, couples and strangers recognized each message at a similar level of accuracy. As shown in Fig. 2A, there was no statistically significant difference between couples and strangers in their recognition. Detailed recognition accuracies are shown in the confusion matrices in Fig. 2B. For most of the messages, their recognition accuracies were much higher than chance (14.3%). Moreover, as shown in Fig. 2C, strangers tended to recognize received contact as the attention message

much more frequently than couples. While each message was expressed for 60 trials (14.3%) in total by touchers, attention was recognized by stranger receivers in 118 trials (28.9%).

In contrast to their comparable message recognition performance, romantically involved receivers reported higher ratings of valence and arousal than strangers. As shown in Fig. 2D, couples perceived holding contact, and especially stroking contact, to be significantly more pleasant than strangers. In addition, among seven emotional messages, five of them, including sympathy, gratitude, attention, calm, and happiness, were reported to be significantly more pleasant by couples. For arousal ratings, the tapping gesture and attention message were perceived to be significantly more emotionally intense by couples than strangers (Fig. 2E).

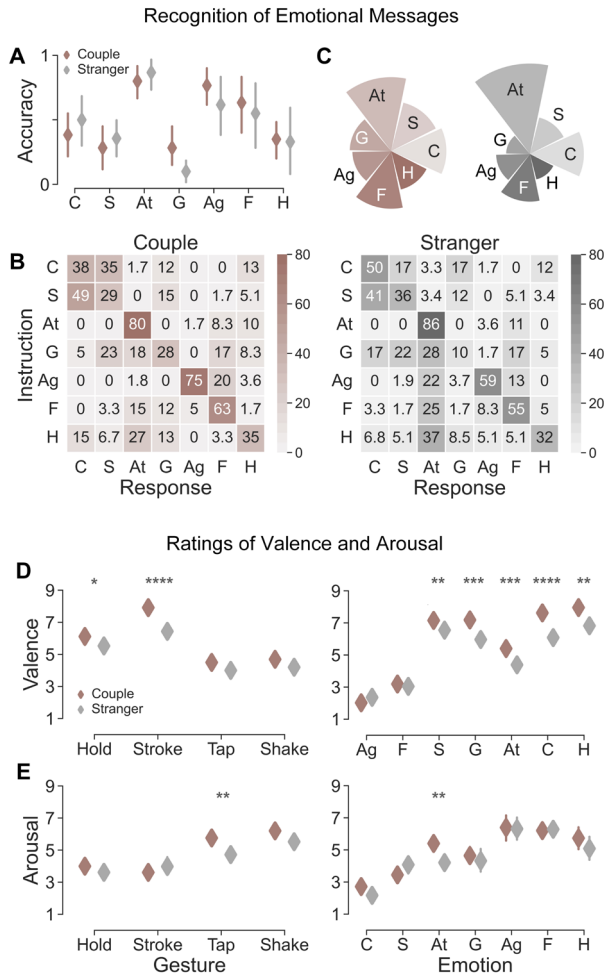


Figure 2. (A) Comparison of recognition accuracy of each emotional message between couples and strangers. Diamonds denote means, error bars denote 95% confidence intervals. (B) Confusion matrices of emotional message recognition for couples and strangers. (C) Frequency of recognized emotional messages for couples and strangers. (D) Valence ratings of each gesture and emotional message. (E) Arousal ratings of each gesture and emotional message. Diamonds denote means, error bars denote 95% confidence intervals. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, **** $p < 0.0001$ were derived by Mann-Whitney U tests with Benjamini-Hochberg post-hoc correction. Cohen's effect sizes for significantly different pairs were 0.298, 1.20, 0.531, 1.03, 0.705, 1.07, 0.942, 0.396, 0.5 (from left to right, valence to arousal).

B. Couples Deliver Contact in a Distinct Way

Touchers also changed gestures and contact attributes when switching between touching their partner and the stranger. As shown in Fig. 3A, couples selected all four

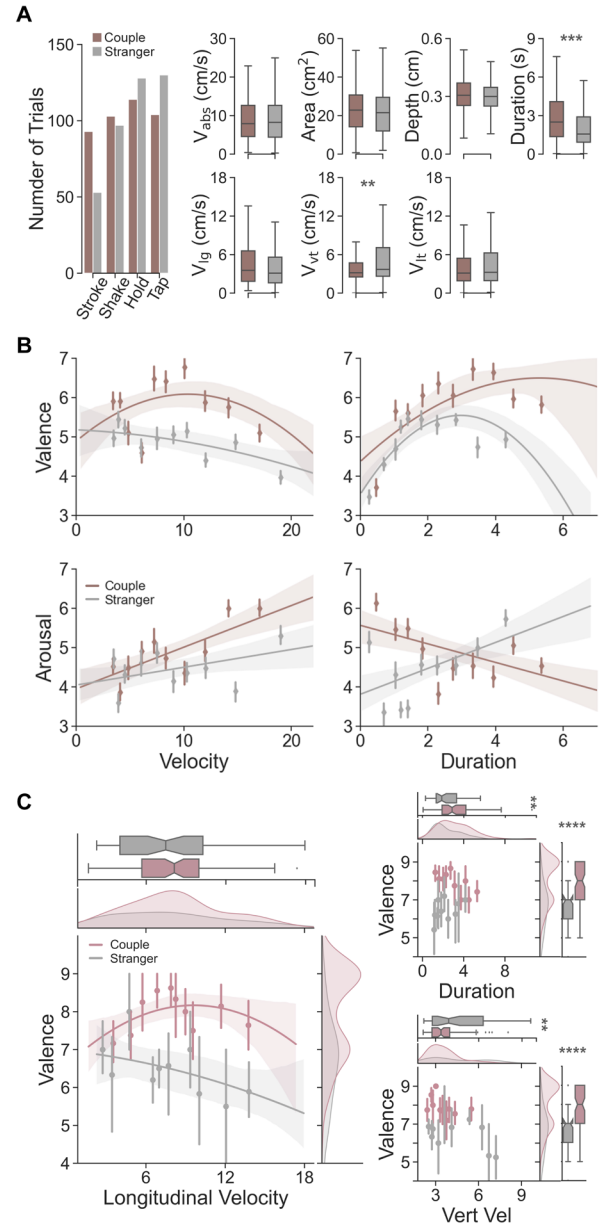


Figure 3. (A) Left: Total number of trials each gesture is selected by couples and strangers respectively. Right: The distribution of contact attributes deployed by couples and strangers. V_{abs} : absolute contact velocity, V_{lg} : longitudinal velocity, V_{vt} : vertical velocity, V_{lt} : lateral velocity. (B) Correlation between contact attributes and valence, arousal ratings across couples and strangers with all gestures combined. Quadratic regression was applied for valence and linear regression was applied for arousal. Bands around regression curves denote 95% confidence intervals. (C) Quadratic regressions between longitudinal velocities and valence ratings for the stroking gesture across couples and strangers. For regressions in panel B and C, data points denote means of raw data grouped by 10 even bins and error bars denote 95% confidence interval. For the comparison of contact attributes in panel A and C, ** $p < 0.01$, *** $p < 0.001$, **** $p < 0.0001$ were derived by linear mixed effects model with Benjamini-Hochberg post-hoc correction. Partial η^2 effect sizes were 0.07, 0.02, 0.08, 0.07 for (A) duration, vertical velocity, (C) duration, vertical velocity, respectively.

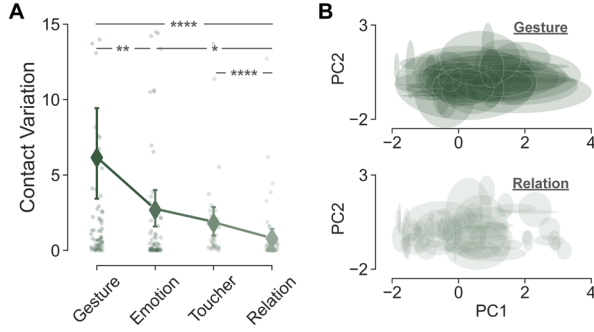


Figure 4. (A) Contact variation caused by varying a factor while the other three factors remain the same. Data points denote contact variations var^{ci} of valid conditions. Diamonds denote means, which are contact variations var caused by factors. Error bars denote 95% confidence intervals. $*p < 0.05$, $**p < 0.01$, $***p < 0.0001$ were derived by Mann-Whitney U tests with Benjamini-Hochberg post-hoc correction. (B) Contact variations of valid conditions visualized by two PCs of contact attributes. Ellipses are associated with data points in panel A, which are valid conditions defined above. The center of the ellipse denotes the mean value of PC1 and PC2 over all gestures/relationships within that condition. Semi-major and semi-minor axes are the standard deviations on PC1 and PC2, respectively. Larger area implies larger contact variation of the condition.

gestures with similar frequencies, while strangers tended to use more tapping and holding gestures and avoided stroking gesture. From the distribution of contact attributes, couples delivered contact with significantly longer contact duration ($p < 0.0001$) and significant lower vertical velocities ($p < 0.01$).

C. Couples Exhibit Different Correlations between Contact Attributes and Affective Ratings

Correlations between valence/arousal ratings and contact attributes were also different across couples and strangers. As shown in Fig. 3B, an inverted-U shape relationship can be observed between valence ratings and spatial contact velocities for couples (quadratic regression, $p = 0.0135$, $\eta^2 = 0.02$). In contrast, quadratic regression shows a decreasing correlation between them for strangers (linear regression, $p < 0.001$, $\eta^2 = 0.03$). Meanwhile, the curve fitted for couples was overall above that of strangers in the same coordinate. A quadratic function was also fitted for valence ratings relative to contact durations for both couples ($p < 0.0001$, $\eta^2 = 0.09$) and strangers ($p < 0.0001$, $\eta^2 = 0.16$). The curve for strangers began to decrease at around 3 s. Yet the curve for couples kept increasing (linear regression, $p < 0.0001$, $\eta^2 = 0.06$). As for arousal, the ratings reported by couples increased when contact velocity increased (linear regression, $p < 0.0001$, $\eta^2 = 0.05$), while decreased for strangers (linear regression, $p < 0.0001$, $\eta^2 = 0.08$). More interestingly, when contact duration increased, arousal rated by couples decreased (linear regression, $p < 0.0001$, $\eta^2 = 0.04$), but increased for strangers (linear regression, $p < 0.01$, $\eta^2 = 0.02$).

Especially for stroking gesture (Fig. 3C), an inverted-U shape curve was fitted between valence ratings and longitudinal velocities for couples (quadratic regression, $p = 0.0482$, $\eta^2 = 0.07$). Yet quadratic regression exhibits a decreasing trend for strangers. Distributions of contact attributes and valence ratings are also shown as marginal kernel density estimation plots and box plots. Longitudinal

velocities deployed by couples and strangers exhibit similar median values, but data from couples concentrate more around 8-10 cm/s, while that from strangers were distributed more evenly. Moreover, as valence ratings for couples being significantly higher than strangers, contact durations ($p < 0.01$) and vertical velocities ($p < 0.01$) deployed by couples were significantly higher and lower than strangers, respectively.

D. Relationship Has the Least Impact on Contact Delivery

As shown in Fig. 4A, contact variation caused by relationship status was significantly lower than that of the three other factors. More specifically, the ranking of the impact from the highest to the lowest was: gesture > emotional message > individual toucher > relationship status. Contact variation var of each factor as calculated in III-D was represented as a diamond in Fig. 4A. Contact variations var^{ci} of valid conditions were represented as data points in Fig. 4A, with two PCs from the contact attributes represented as ellipses in Fig. 4B. Those ellipses tied to relationship status exhibit smaller areas than those tied to gesture, indicating that relationship status leads to less variation in contact attributes.

V. DISCUSSION

This work explores how relationship status influences our delivery and perception of social touches and emotions, by precisely measuring physical contact interactions. Similar to prior studies [8], [9], [19], we find that romantically involved couples perceive social touch as emotionally more pleasant and intense than touch from strangers. Measurements of hand-forearm contact interactions illustrate that couples indeed deliver contact and perceive contact changes differently from strangers. For instance, in stroking contact, significantly more pleasant sensations perceived by romantic receivers may result from the fine tuning of contact attributes, including velocities preferential to C-tactile afferents, and contact delivered for longer durations of time with larger contact areas. To put these findings in context, however, compared with factors of gesture, emotional message, and individual toucher, one's relationship status introduces relatively less impact on the delivery of contact interactions. Notwithstanding, the findings suggest that finely tuned contact interactions do still modulate the affective percepts of receivers in significant ways.

A. Relationship Impacts Affective Percepts

By evaluating responses from touch receivers, we find that relationship status does not affect one's recognition of emotional messages, yet it does influence their affective percepts. In particular, in terms of valence ratings, in line with prior studies [8], [9], [11], contact from one's partner as opposed to a stranger, especially gentle stroking [19], was perceived as much more pleasant (Fig. 2D). Indeed, among all gestures, gentle stroking has been shown to be the preferred stimulus for C-tactile afferents, which may drive valence ratings [20], [31]. In terms of recognition, we found that universal emotions (anger, fear, happiness) and prosocial emotions (gratitude, sympathy) were communicated by couples and strangers in similar ways (Fig. 2A). Such insignificance in recognition accuracy aligns with prior findings [7], and helps validate the feasibility of our experimental paradigm.

B. Relationship Impacts Contact Delivery that Modulates Affective Percepts

Analysis of physical contact illustrates that relationship status affects touchers' strategies. As noted, couples frequently choose the stroking gesture, which strangers avoid (Fig. 3A). Indeed, stroking is a more intimate gesture and might be considered inappropriate to strangers. Moreover, couples deliver contact with longer durations as compared with strangers of less than 3 s (Fig. 3A). Strangers also deploy higher vertical velocities, which could be related to their preference of tapping gesture, as well as being more abrupt in how they make contact overall, regardless of gesture.

On the receiver side, couple and stranger receivers respond distinctly to changes in delivered contact. Specifically, increased contact durations are perceived as more pleasant, less intense by romantically involved receivers, while valence drops and arousal rises for strangers after 3 seconds (Fig. 3B). This indicates that strangers do not prefer prolonged physical contact as natural and comfortable, and thus, when touching strangers, delivered contact does not typically last long.

Furthermore, our results indicate that touchers fine tune their contact delivery according to specific affective responses when relationship status changes. Specifically for the stroking gesture, an inverted-U curve of pleasantness is observed for couples with a peak around 8-10 cm/s longitudinal velocities (Fig. 3C), which aligns with preferred stroking velocities for CT afferents in brushing experiments [20]. Meanwhile, longitudinal velocities delivered by couples also concentrated around 8-10 cm/s. This alignment between the pleasantness curve and the velocity distribution indicates that couples may finely adjust their stroking velocities towards an optimal range of pleasantness. In contrast, valence ratings of strangers do not follow the inverted-U pattern and their longitudinal velocities distribute evenly without any peak. It indicates that strangers might be indifferent to deliver pleasant contact during social touch communication. Moreover, the specific stroking pattern of couples, i.e., longitudinal velocities with CT-targeted range, more gentle contact with lower vertical velocities, and longer contact durations, could be related to the bottom-up neural signaling of pleasantness, on top of the influence of relationship being a top-down contextual factor [32].

C. Impact of Relationship is Significant but Subtle

We find that relationship status introduces the least impact on contact delivery compared with other factors. Among prior studies in social touch, qualitative observation may hinder the comparison of contextual factors' relative importance. Herein, we measured their relative impact based on physical contact attributes. The ranking obtained for the four factors was of the following order: gesture > emotional message > individual toucher > relationship status. This order indicates that gesture types lead to highly differentiable physical contact attributes. Emotional and social meanings may also shape adjustments to contact patterns, and to a lesser extent individual differences in touch preferences. The most subtle contact variation, due to relationship status, might explain similar recognition performance between couples and strangers. However, although subtle, impact of relationship is still significant in shaping the delivery of contact attributes so as to modulate affective percepts.

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