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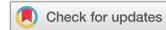
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Asymmetries in social touch—motor and emotional biases on lateral preferences in embracing, cradling and kissing

Julian Packheiser^{a†}, Judith Schmitz^{a†}, Dorothea Metzen^a, Petunia Reinke^a, Fiona Radtke^a, Patrick Friedrich ^a, Onur Güntürkün^a, Jutta Peterburs^b and Sebastian Ocklenburg ^{a,c}

^aInstitute of Cognitive Neuroscience, Biopsychology, Department of Psychology, Ruhr-University Bochum, Bochum, Germany; ^bBiological Psychology, Heinrich-Heine-University Düsseldorf, Düsseldorf, Germany; ^cDepartment of Psychology, University of Duisburg-Essen, Essen, Germany

ABSTRACT

In human social interaction, affective touch plays an integral role to communicate intentions and emotions. Three of the most important forms of social touch are embracing, cradling and kissing. These behaviours have been demonstrated to be lateralized, but the underlying mechanisms are still not well understood. Both motor and emotive biases have been suggested to affect laterality of social touch. We aimed to systematically investigate how motor preferences and emotive biases influence the lateralization of embracing, cradling and kissing within the same sample. Participants performed all three forms of social touch in neutral, positive and negative emotional conditions. Like a previous study, we found a rightward bias for embracing that was modulated by both motor preferences and the emotional content of the situation. Kissing and cradling were not influenced by motor preferences. In general, a negative emotional connotation of the situation led to a reduction of lateral biases in social touch, independent of the individual direction.

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KEYWORDS Social neuroscience; emotion; lateralization; social touch; affective touch

Introduction

In humans and non-human primates alike, tactile interaction with other conspecifics is a fundamental form of social behaviour to communicate emotional states and social intentions. Humans experience social touch from birth onwards. The first social interaction of an infant is being cradled in its

CONTACT Julian Packheiser  julian.packheiser@rub.de

[†]These authors contributed equally to the manuscript.

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mother's arms (Forsell & Åström, 2012). Other important forms of tactile social interactions are kissing and embracing. Interestingly, a population bias on the lateralization of cradling (Almerigi, Carbary, & Harris, 2002; Fleva & Khan, 2015; Salk, 1960), kissing (Barrett, Greenwood, & McCullagh, 2006; Güntürkün, 2003; Ocklenburg & Güntürkün, 2009) and embracing (de Lussanet, 2019; Packheiser, Rook, et al., 2019; Turnbull, Stein, & Lucas, 1995) has been observed in humans indicating that there is a general preference to use one side over the other while engaging in social touch. For cradling, it should be noted that the bias does not seem to be present from birth, indicating that preferences in social touch might be socially, rather than genetically, transmitted (Forrester & Todd, 2018).

As cradling, kissing and embracing all include a motor action, it is conceivable that the underlying mechanism depends on a motor preference (Ocklenburg et al., 2018; Ocklenburg & Güntürkün, 2017; Ocklenburg, Beste, & Güntürkün, 2013; Ocklenburg, Beste, Arning, Peterburs, & Güntürkün, 2014). Handedness provides a highly lateralized human phenotype that demonstrates a strong preference for the use of the right hand with about 90% of individuals being right-handed (Corballis, 2014; Güntürkün & Ocklenburg, 2017; Ocklenburg & Güntürkün, 2017; Schmitz et al., 2019; Schmitz, Metz, Güntürkün, & Ocklenburg, 2017).

For embracing, only two studies have systematically investigated its lateralization (Packheiser, Rook, et al., 2019; Turnbull et al., 1995). Both studies used a combinatory approach consisting of an observational field and controlled laboratory experiment to determine if embraces are overall lateralized and if this potential lateralization is determined by motor biases. Each study reported a rightward bias of embraces, but only the study by Packheiser, Rook, et al. (2019) could find a significant correlation of handedness and footedness with the direction of the embrace.

For cradling, an initial study of Salk (1960) reported no differences between left- and right-handers for a cradling bias with both of them demonstrating a comparable leftward bias indicating against a motor bias. However, a large-scale study (van der Meer & Husby, 2006) investigating 765 participants reported a strong leftward bias for right-handers and a strong rightward bias for left-handers. The preference to use the non-dominant hand for cradling was interpreted to be associated with the remaining ability to conduct more fine-tuned motor task using the dominant hand. A recent meta-analysis on the cradling bias however found that handedness, while being a significantly contributing moderator, does not fully explain the cradling bias (Packheiser, Schmitz, Berretz, Papadatou-Pastou, & Ocklenburg, 2019). Left-handers continue to be left-preferent overall in their cradling bias, their preference is merely shifted significantly to the right. This result is consistent with findings of studies demonstrating the left cradling bias remains even in situations when there is no demand to keep the dominant hand free (Todd & Banerjee, 2016).

For kissing, an initial report of a rightward bias was given by Güntürkün (2003) who observed people kissing in public places. While these results could be replicated in several laboratory studies, findings regarding the relationship between kissing lateralization and motor biases were controversial. Ocklenburg and Güntürkün (2009) and Karim et al. (2017) both found a substantial contribution of handedness and footedness to the lateralization of kissing, but a corresponding finding was not evident in other studies (Barrett et al., 2006; van der Kamp & Canal-Brundland, 2011).

Taken together, the results do not show a clear indication that motor preferences influence the lateralization of human touch. However, most studies investigating well-powered samples found significant motor influences in contrast to studies with low statistical power implying that the effects are most likely small in size and therefore not easily detected (e.g., Nakamichi & Takeda, 1995; for review, see Ocklenburg et al., 2018).

Another possible influence on the lateralization of human social touch could stem from emotional influences during tactile interactions (Ocklenburg et al., 2018). All aforementioned social touch phenomena can occur in situations of positive, negative as well as neutral emotional valence. For example, embracing can take place in situations that are either emotionally neutral (greetings), negative (consoling someone who is grieving) or positive (hugging someone beloved). Since emotional processing has been demonstrated to be lateralized, the difference in emotionality could potentially affect side biases in social touch.

There are two major theories of emotional lateralization that could differentially impact lateralization of human social interaction (Demaree, Everhart, Youngstrom, & Harrison, 2005). One major hypothesis is the right hemisphere hypothesis (RHH) that suggests that the right hemisphere is dominant in processing of positive and negative emotions alike. This theory has been supported by a large body of evidence using various neuroscientific methods (Adolphs, Damasio, Tranel, & Damasio, 1996; Borod et al., 1998; Godfrey & Grimshaw, 2016; Innes, Burt, Birch, & Hausmann, 2016; Narumoto, Okada, Sadato, Fukui, & Yonekura, 2001; Sato, Kochiyama, Yoshikawa, Naito, & Matsu-mura, 2004; de Winter et al., 2015; for review, see Schirmer & Adolphs, 2017). For the lateralization of social touch, the RHH predicts a leftward shift in behaviour in emotional situations compared to neutral situations due to a stronger activation of right-hemispheric neural networks. Another major theory postulates a valence-specific processing by the two hemispheres (Ahern & Schwartz, 1979). According to this theory, the left hemisphere is dominant for positive emotional processing while the right hemisphere is dominant for negative emotional processing. As for the RHH, the valence model (VM) has also received substantial empirical support using electrophysiological and neuroimaging techniques (Baijal & Srinivasan, 2011; Canli, Desmond, Zhao, Glover, & Gabrieli, 1998; Ekman & Davidson, 1993; Waldstein

et al., 2000; Wyczesany et al., 2011; Wyczesany, Capotosto, Zappasodi, & Prete, 2018). Furthermore, recordings of frontal alpha power using EEG have been demonstrated to be lateralized in accordance with the VM (for review, see Reznik & Allen, 2018). The VM would predict both a rightward shift in lateralization of social touch in positive situations and a leftward shift in negative situations compared to neutral situations. It should be noted that evidence in favour of any of the two theories directly contradicts the other as the RHH and the VM are mutually exclusive. However, in the recent past, there have been efforts to integrate these contradictory findings in the literature about emotional hemispheric lateralization. Killgore and Yurgelun-Todd (2007) found that emotional face processing is right-lateralized in posterior brain regions irrespective of valence whereas frontal regions were activated in accordance with the VM. Based on these findings, they proposed that there might be two different neural systems, namely a posterior one for emotion perception in general (RHH) and a frontal one for emotional experience and evaluation (VM). Another model proposed that the VM represents a default mode in the brain and only during decision making, a valence unspecific right hemispheric dominance in emotional processing emerges (Prete, Laeng, Fabri, Foschi, & Tommasi, 2015). These integrational accounts can therefore explain why the literature has been largely inconclusive on the topic of emotional lateralization in the brain.

Studies systematically investigating the role of emotional state on the lateralization of social behaviour are sparse. A strong indication that the emotional context affects the lateralization of social touch was found in a study investigating embracing (Packheiser, Rook, et al., 2019). Here, the direction of the embrace was significantly more left-shifted in positive and negative emotional contexts compared to neutral ones. For cradling, no direct behavioural evidence has been generated on how different emotional situations affect its lateralization. However, it has been theorized that the left-side bias is related to a preference to keep the child in the left visual half-field projecting to the right hemisphere (Manning & Chamberlain, 1991). This has been supported by a study investigating the relationship between the cradling bias and the dominant hemisphere in facial affective processing using a chimeric faces task (Bourne & Todd, 2004). The authors found that female left-cradlers indeed demonstrated a right-hemispheric bias in facial emotion processing indicating a potential influence of emotive processing. In the case of kissing, Barrett et al. (2006) found no difference in lateralization bias between a romantic couple's kiss and a neutral kiss given to a doll in a laboratory experiment suggesting no influence of the emotional context. However, in line with a possible influence of the affective nature of the kiss, a study conducted by Sedgewick and Elias (2016) found a right-turn bias for romantic kisses whereas parental kisses displayed a left-turn bias. Here, a right-sided bias indicates the preference to keep the kissing

partner in the left visual field (right hemisphere) whereas a left-sided bias indicates a preference to keep it out of the left visual field. Furthermore, another study by Sedgewick, Holtslander, and Elias (2019) demonstrated that the right-sided kissing bias is absent when kissing strangers also demonstrating that the emotional context of the situation strongly influences this behaviour. This study further indicates that kissing is even mostly influenced by an emotive bias as no directional bias could be found in a kiss between strangers.

As the role of emotional influences on lateralization in social touch behaviour is still widely unknown, we aimed to investigate if and how the emotional context alters the lateralization bias in cradling, kissing and embracing in a laboratory study using emotional short stories to induce the affective state in the participants. For embracing, this study directly replicates the methodological procedure used in the laboratory study by Packheiser, Rook, et al. (2019) to support their results. Furthermore, cradling and kissing biases are investigated in the same sample to account for inter-individual variance in lateralization bias, thus allowing for a direct comparison between these types of social touch. Based on previous findings, we expect to replicate a general rightward bias for embraces and kisses and a leftward bias for cradling. Furthermore, we expect an effect on the laterality of social touch in all conditions in emotional compared to neutral conditions. Here, we expect a left-shift in emotional compared to neutral conditions since the RHH has so far provided the most pervasive explanation for shifts in lateralization of social touch due to emotive biases (Ocklenburg et al., 2018). Furthermore, a right-hemispheric dominance in processing of emotional faces has been found robustly in the literature (Borod et al., 1998; Innes et al., 2016) which also indicates in favour of the RHH influencing lateral preferences in social touch.

Methods

Participants

We tested 100 healthy adults (50 females) as participants (mean age = 24.79, range from 19 to 37 years). Participants were excluded if they suffered from psychiatric or neurological disorders and if they had visible physical disabilities that potentially biased their choice in the experiment. Packheiser, Rook, et al. (2019) conducted the laboratory part of their study using a similar sample size resulting in robust effects for the lateralization of embracing. All participants signed an informed consent form and all procedures were approved by the Ethics committee of the department of Psychology of the Ruhr University Bochum. All participants were treated in accordance with the Declaration of Helsinki.

Procedure and materials

Participants were tested individually. The experimental room consisted of a computer, two full-size, symmetrically orientated mannequins for embracing, two baby dolls for cradling and two plastic heads mounted to height-adjustable tripods for kissing (Figure 1; we will use the term “inanimate objects” from here on to refer to the objects used in all three tasks). For all forms of social touch, one of the inanimate objects was male and one was female. After giving written consent, the participants were instructed about the general task procedure. The experiment consisted of 30 trials distributed evenly across the three forms of social touch. Each of the three behaviours (embracing, cradling and kissing) was tested twice under neutral conditions (once per inanimate object gender) and four times for both the positive and the negative emotional condition (twice per inanimate object gender). The emotional conditions differed based on oral presentations of short stories in each trial. Using wireless headphones, a short story ranging from 2 to 5 min length was presented to the participants to induce the respective emotion. The stories were designed as such that the participant was directly involved in the narrative and either embraced, cradled or kissed another person at the end of the story. The gender of the other person in the story matched the inanimate object that had to be interacted with in that specific trial. As all participants were German native speakers, the stories were told in German (English translations can be found in the supplements 1, German originals can be found in supplements 2). Before each trial, the participants were asked to stand in front of the respective inanimate object for that particular trial (a marked spot was located 50 cm in front of the inanimate object) and directly look at it for the duration of the story to be fully immersed into the narrative. After the story concluded, the participants were required to perform either an embrace, cradling of the doll or a kiss depending on the trial type. During the experiment, embracing, cradling and kissing trials were randomized across participants. The neutral conditions always preceded the positive and negative conditions to exclude residual emotions from previous trials affecting the behaviour in neutral trials. Thus, the experiment always started with six neutral trials (two for each behaviour) and continued with 24 emotional trials (12 positive and 12 negative) which were presented in a random order. After a block of six trials, the experimental procedure was paused and the participants could sit down to relax shortly. In the pauses, the participants were asked to fill out questionnaires regarding handedness (Edinburgh Handedness Inventory (EHI, Oldfield, 1971)) and footedness (Waterloo Footedness Questionnaires (WFQ, Elias, Bryden, & Bulman-Fleming, 1998)) in addition to providing demographic data (see supplements 3).

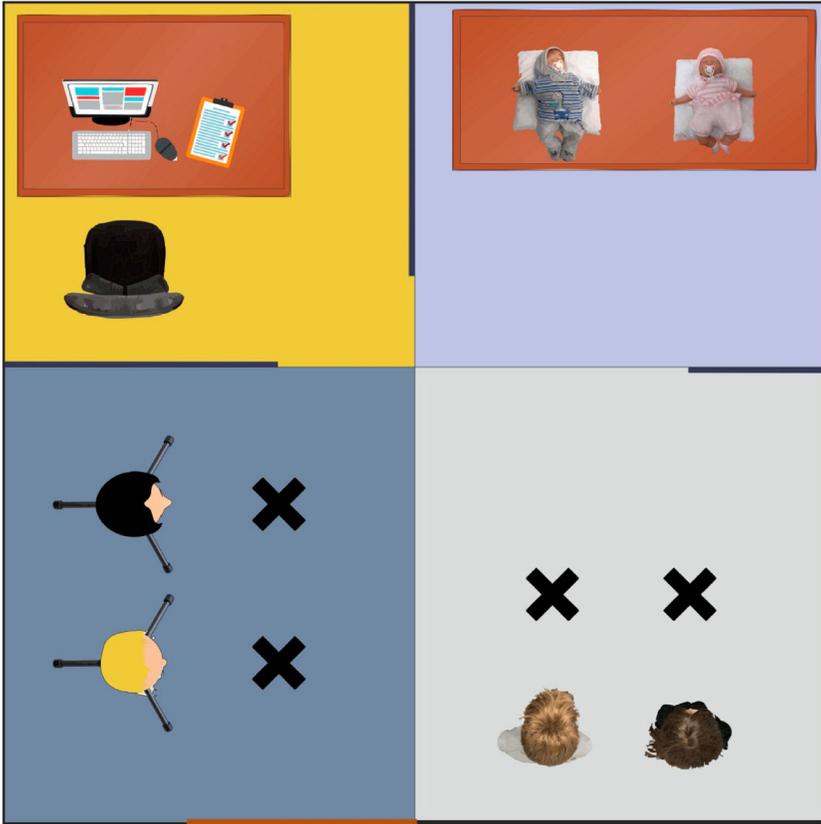


Figure 1. Schematic display of the experimental room. The room was subdivided into four specific areas. In the top-left area, the participants were asked to answer questionnaires and rate the stories after a block of six trials had been concluded. The bottom-left area contained the mounted heads on tripods for the kissing condition. Here, participants were located 50 cm in front of the tripod on a marked X on the ground to listen to the story of the respective trial. The bottom-right area was used for the embracing condition. The two mannequins were located sufficiently far away from the wall and each other for an unrestrained embrace. Again, participants were asked to listen to the story on a marked X located 50 cm in front of the mannequins. The top-right area served for the cradling condition. Two baby dolls were lying on a table while the participants listened to the short story. The black bars represent partitions within the experimental chamber. (To view this figure in color, please see the online version of this journal).

Validation of emotional stories in an independent sample

To determine whether the used short stories induced affective responses, we conducted a validation study. Both emotional valence and the empathy participants felt while reading the story were assessed. For embracing, the stories had already been validated in Packheiser, Rook, et al. (2019). Therefore, we report the same results here. For the cradling and kissing stories, eight

independent (five female, three male) raters were asked to assess the emotional valence on a scale from -5 to $+5$. A rating of -5 indicated a very negative emotional valence whereas a rating of $+5$ indicated a very positive rating. For empathy, the scale ranged from 0 to 10. Here, an empathy score of 0 indicated complete absence of empathy whereas a score of 10 indicated that the participant was well able to take the perspective indicated in the short story. Ratings were analyzed using repeated-measures ANOVAs with the factor story valence used as within-subject factor.

For the embracing stories, a significant main effect of valence could be detected ($F_{(2,16)} = 105.90, p < 0.001, \eta_p^2 = 0.93$, Figure 2a). The positive stories were rated significantly more positive (mean score = 3.58, 95% CI = [2.71, 4.46]) than neutral (mean score = 1.22, 95% CI = [0.48, 1.97], $p = 0.014$) and negative stories (mean score = -3.67 , 95% CI = [$-4.44, -2.90$], $p < 0.001$). Empathy scores were high across all stories (mean score = 7.41, 95% CI = [6.79, 8.02]). Valence did not affect empathy ratings ($F_{(2,16)} = 0.47, p > 0.250, \eta_p^2 = 0.05$).

For the cradling stories, we found similar results for the ratings ($F_{(2,14)} = 124.06, p < 0.001, \eta_p^2 = 0.95$, Figure 2b). Positive stories had a mean rating of 3.63 (95% CI = [3.14, 4.11]) and were rated significantly more positively than neutral (mean score = 0.56, 95% CI = [0.09, 1.03], $p < 0.001$) and negative stories (mean score = -2.22 , 95% CI = [$-3.12, -1.32$], $p < 0.001$). Neutral stories also received higher ratings than negative stories ($p < 0.001$). Empathy scores were also high for all stories (mean score = 6.54, 95% CI = [5.02, 7.88]) and did not significantly differ with regards to the emotional valence of the story ($F_{(2,14)} = 2.66, p = 0.105, \eta_p^2 = 0.28$).

For kissing, we also found significant differences between the story types in terms of valence ($F_{(2,14)} = 72.03, p < 0.001, \eta_p^2 = 0.91$, Figure 2c). As before, positive stories received higher ratings (mean score = 3.81, 95% CI = [3.27, 4.36]) than neutral (mean score = 0.63, 95% CI = [$-0.20, 1.45$], $p < 0.001$) and

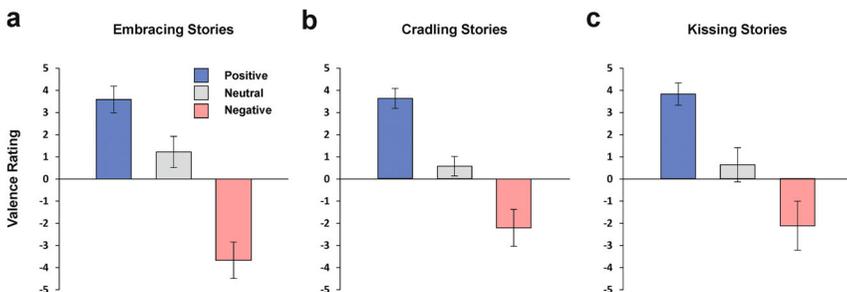


Figure 2. Validation of short stories for (a) embracing, (b) cradling and (c) kissing in an independent sample. Blue bars indicate ratings for positive stories, grey bars indicate ratings for neutral stories and red bars indicate ratings for negative stories. Error bars represent 95% CIs. (To view this figure in color, please see the online version of this journal).

negative stories (mean score = -2.13 , 95% CI = $[-3.31, -0.94]$, $p < 0.001$). Neutral stories also were rated more positively than negative stories ($p = 0.006$). Empathy score were also generally high (mean score = 7.08 , 95% CI = $[6.10, 8.07]$) and did not differ between the short story types ($F_{(2,14)} = 1.53$, $p > 0.250$, $\eta_p^2 = 0.18$).

Rating of emotional stories

In addition to the validation of the short story prior to data collection, we also asked the participants to rate the short stories following the same protocol as in the validation study.

Data analysis

We computed lateralization quotients (LQs) for handedness and footedness as determined by the EHI and WFQ questionnaires for all participants as well as for embracing, cradling and kissing across the experimental conditions and separately for each condition. The LQ ranges between -100 and $+100$ where a value of $+100$ reflects consistent right-side preference whereas a value of -100 indicates consistent left-side preference. Gender differences in LQs were tested using t -tests. Based on their LQs, participants were classified as being right-preferent (LQ = $+41$ to $+100$) ambilateral (LQ = -40 to $+40$) or left-preferent (LQ = -41 to -100). These cut-offs have been used by a previous study (Li, Zhu, & Nuttall, 2003) who derived them based on the findings of an earlier study on the link between handedness and cognitive abilities (Burnett, Lane, & Dratt, 1982).

Results

Rating of short stories

Empathy scores for the short stories were high for the embracing condition indicating that participants were successfully immersed in the scenarios (mean empathy score = 7.40 , 95% CI = $[7.10, 7.70]$). There was no difference between male and female participants regarding the empathy scores ($t_{(98)} = 0.59$, $p = 0.559$, $d = 0.12$). The repeated measure ANOVA comparing the different emotional conditions revealed a significant effect ($F_{(2,196)} = 70.27$, $p < 0.001$, $\eta_p^2 = 0.42$). Positive short stories received a higher rating (mean = 3.24 , 95% CI = $[2.99, 3.48]$) than neutral (mean = 1.78 , 95% CI = $[1.50, 2.05]$, $p < 0.001$) and negative stories (mean = -0.12 , 95% CI = $[-0.71, -0.46]$, $p < 0.001$). Furthermore, neutral stories also received significantly higher ratings than negative stories ($p < 0.001$). The interaction condition*gender did not reach significance ($F < 1$).

As for the embracing stories, the cradling stories also elicited high empathy ratings (mean = 6.59, 95% CI = [6.24, 6.93]). Again, gender did not have a significant influence on empathy scores ($t_{(98)} = 0.63$, $p = 0.525$, $d = 0.13$). Valence of the stories demonstrated a significant effect ($F_{(2,196)} = 197.43$, $p < 0.001$, $\eta_p^2 = 0.67$). Positive stories were rated higher (mean = 3.30, 95% CI = [3.04, 3.57]) than both neutral (mean = 1.56, 95% CI = [1.26, 1.85], $p < 0.001$) and negative stories (mean = -0.46, 95% CI = [-0.77, -0.14], $p < 0.001$). Neutral and negative stories also differed significantly ($p < 0.001$). The interaction condition*gender had no effect on the ratings ($F < 1$).

Empathy scores for the kissing stories were high (mean = 6.83, 95% CI = [6.51, 7.16]) and unaffected by participant gender ($t_{(98)} = 1.67$, $p = 0.098$, $d = 0.33$). Comparable to the other short stories, the factor emotional condition produced a significant effect for the valence ratings ($F_{(2,196)} = 274.27$, $p < 0.001$, $\eta_p^2 = 0.74$). As before, positive stories elicited the highest ratings (mean = 3.03, 95% CI = [2.70, 3.37]), neutral stories intermediate ratings (mean = 0.92, 95% CI = [0.51, 1.32]) and negative stories the lowest ratings (mean = -2.12, 95% CI = [-2.43, -1.80]). All story ratings were significantly different from each other ($p < 0.001$). The interaction between emotional condition and participant gender was significant ($F_{(2,196)} = 7.00$, $p = 0.001$, $\eta_p^2 = 0.07$).

Thus taken together, participants successfully immersed in the narrative of the stories in all three conditions. Moreover, positive stories received the most positive, neutral stories a medium and negative stories the most negative rating in all three conditions.

Handedness and footedness

For handedness and footedness, mean LQs were 69.09 (95% CI = [58.54, 79.63]) and 46.76 (95% CI = [39.25, 54.27]), respectively. According to their LQs, eleven participants were classified as left-handed and 89 participants as right-handed. There were no ambidextrous participants in the sample. Handedness and footedness were significantly correlated ($r_{(99)} = .653$, $p < 0.001$). Gender did not significantly affect the LQs for handedness ($t_{(98)} = 1.31$, $p = 0.193$, $d = 0.26$) and footedness ($t_{(98)} = 0.63$, $p = 0.529$, $d = 0.13$).

Social touch: categorical analysis: distribution and relation to emotion

Based on their LQs, participants were categorized as being either left-, or right-preferent, or ambilateral (see Table 1). A significant rightward preference was observed for all embracing and cradling categories, as well as the positive category for kissing (see table for detailed statistics). For the negative and the neutral condition for kissing, no significant preference for one category was detected.

Table 1. Percentage of right-preferent, left-preferent and ambilateral participants for the three emotional conditions and the three forms of social touch.

		Right	Ambilateral	Left	χ^2	p
Embracing	Neutral	65%	29%	6%	53.06	<0.001*
	Positive	54%	40%	6%	36.56	<0.001*
	Negative	52%	36%	12%	24.32	<0.001*
Cradling	Neutral	44%	23%	33%	6.62	<0.05*
	Positive	50%	20%	30%	14.00	<0.01*
	Negative	50%	22%	28%	13.04	<0.01*
Kissing	Neutral	36%	38%	26%	2.48	0.29 ns
	Positive	46%	21%	33%	9.38	<0.05*
	Negative	40%	32%	28%	2.24	0.37 ns

Asterisks indicate significance at the $p < 0.05$ level.

Based on these data, we then assessed whether there was a change in side preferences in social touch in the emotional compared to the neutral condition. To this end, we compared the individual preferences of participants in the two emotional conditions to the neutral condition for three forms of social touch using non-parametric Wilcoxon tests (see Table 2). The comparison reached significance only for the neutral to negative comparison for embracing ($Z = -2.81$; $p < 0.05$). Here, 13% of participants moved away from a right-sided preference to either ambilaterality (7%) or a leftward preference (6%), indicating a significant leftward shift in side preference in this condition.

Social touch: categorical analysis: relation to motor asymmetries

In order to assess whether there was a link between side preferences in social touch and motor bias, we calculated univariate ANOVAs with EHI and WFQ LQs as dependent variable and lateral preferences for embracing, cradling and kissing as between-subjects variable (see Table 3 for results). For cradling and embracing, the analyses failed to reach significance for all three conditions. For embracing, a significant effect of side preference in social touch on EHI LQ was observed for the neutral ($p < 0.05$) and positive condition ($p < 0.05$), but not the negative condition ($p < 0.01$). In the neutral condition, participants with a preference to embrace leftwards had a lower EHI LQ (mean = 28.62; 95% CI = [-52.06, 109.31]) than participants who had no side

Table 2. Percentage of participants that changed their side bias in the emotional conditions of the three forms of social touch compared to the neutral condition.

		Right	Ambilateral	Left	Z	p
Embracing	Positive	-11%	+11%	$\pm 0\%$	-1.78	0.076 ns
	Negative	-13%	+7%	+6%	-2.81	<0.01*
Cradling	Positive	+6%	-3%	-3%	-1.08	0.28 ns
	Negative	+6%	-1%	-5%	-1.49	0.14 ns
Kissing	Positive	+10%	-17%	+7%	-0.47	0.64 ns
	Negative	+4%	-6%	+2%	-0.31	0.75 ns

Asterisks indicate significance at the $p < 0.05$ level.

Table 3. ANOVA results for the handedness analysis for right-preferent, left-preferent and ambilateral participants for the three emotional conditions and the three forms of social touch.

		<i>F</i>	<i>p</i>	η^2
Embracing	Neutral	3.74	<0.05*	0.07
	Positive	3.70	<0.05*	0.07
	Negative	2.08	0.13 ns	0.04
Cradling	Neutral	0.01	0.99 ns	0.00
	Positive	0.85	0.43 ns	0.01
	Negative	0.46	0.64 ns	0.01
Kissing	Neutral	0.48	0.61 ns	0.01
	Positive	0.67	0.52 ns	0.01
	Negative	1.67	0.19 ns	0.03

Asterisks indicate significance at the $p < 0.05$ level.

preference when embracing (mean = 86.75; 95% CI = [75.38, 98.14]) or participants that had a preference to embrace rightwards (mean = 64.94; 95% CI = [50.92, 78.95]). Similar results were also observed for the positive condition for embracing (leftward preference: mean = 27.41, 95% CI = [-71.12, 125.95]; ambilateral: mean = 82.93, 95% CI = [71.88, 93.98]; rightward preference: mean = 63.46, 95% CI = [48.05, 78.87]).

Social touch: categorical analysis: intercorrelations

In order to determine whether laterality in the three forms of social was correlated, we determined the Spearman correlation coefficient as a parameter-free measure of correlation. For the neutral condition, there was a significant positive correlation between embracing and cradling ($r = 0.24$; $p < 0.05$). All other correlation coefficients failed to reach significance (all $ps > 0.78$). For the negative and positive conditions, all correlation coefficients failed to reach significance (all $ps > 0.20$).

Social touch: LQ analysis

LQs for embracing, cradling and kissing were analyzed using a 3×3 repeated-measured ANOVA with the within-subjects factors behaviour (embracing, cradling and kissing) and emotional condition (neutral, positive, negative). **Figure 3A** shows the LQs for the different behaviours and emotional conditions.

Here, the analysis revealed a significant main effect of behaviour ($F_{(2,99)} = 10.15$; $p < 0.001$; partial $\eta^2 = 0.09$), indicating higher LQs for embracing (mean = 45.06; 95% CI = [34.89, 55.23]) than for cradling (mean = 17.36, 95% CI = [2.88, 31.84]) and kissing (mean = 10.90, 95% CI = [-2.87, 24.68]). The main effect of emotional condition failed to reach significance ($p = 0.36$). Moreover, there was a significant interaction of behaviour * emotional condition ($F_{(2,99)} = 3.39$; $p < 0.05$; partial $\eta^2 = 0.03$). To disentangle this effect, Bonferroni-

corrected post-hoc tests were calculated. For embracing, a significant difference was found between neutral and positive ($p < 0.05$) and neutral and negative ($p < 0.01$). The positive vs. negative comparison failed to reach significance ($p = 0.08$). Thus, the emotional conditions generally had a lower LQ, irrespective of valence. For cradling and kissing, all Bonferroni-corrected post-hoc tests failed to reach significance (all $ps > 0.19$).

Social touch: absolute LQ analysis

Since the LQ is a continuous measure ranging from -100 to $+100$, grouping left- and right-preferent individuals together for analysis could result in an averaging out of potential effects, making the previous analysis somewhat uninformative. Since the categorical analyses indicated that for kissing and cradling a substantial number of participants were observed for all three categories, we additionally performed an analysis of absolute LQs. This was done in order to assess whether strength of the LQ changed in the emotional compared to the neutral conditions, independent of the direction of preference. Figure 3B shows the absolute LQs for the different behaviours and emotional conditions.

Absolute LQs for embracing, cradling and kissing were analyzed using a 3×3 repeated-measures ANOVA with the within-subjects factors behaviour (embracing, cradling and kissing) and emotional condition (neutral, positive, negative). Here, the analysis revealed a significant main effect of behaviour ($F_{(2,99)} = 3.48$; $p < 0.05$; partial $\eta^2 = 0.03$), indicating higher absolute LQs for cradling (mean = 74.76; 95% CI = [69.37, 80.15]) than for kissing (mean = 67.89; 95% CI = [61.85, 73.93]) and embracing (mean = 65.41; 95% CI = [59.26, 71.58]). Bonferroni-corrected post-hoc tests reached significance for

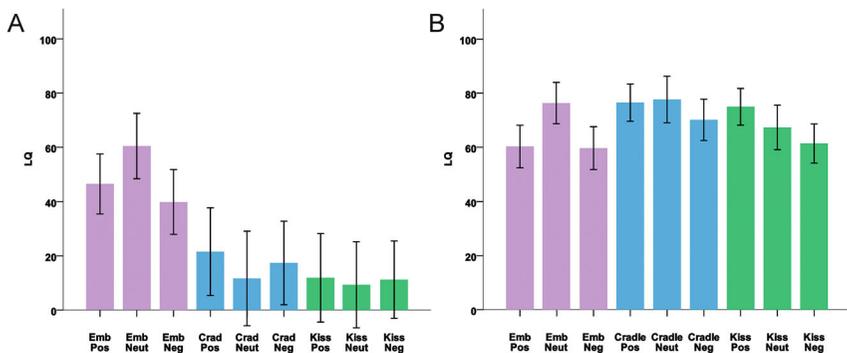


Figure 3. LQs (A) and absolute LQs (B) for embracing (purple bars), cradling (blue bars) and kissing (green bars) for the neutral, positive and negative emotional conditions. Error bars represent 95% CIs. (To view this figure in color, please see the online version of this journal).

the comparison between embracing and cradling ($p < 0.05$). All other comparisons failed to reach significance. Moreover, there was a significant main effect of emotional condition ($F_{(2,99)} = 7.60$; $p < 0.01$; partial $\eta^2 = 0.07$), indicating an lower absolute LQ in the negative emotion condition (mean = 63.72; 95% CI = [58.54, 68.91]), than in the neutral condition (mean = 73.78; 95% CI = [68.48, 79.07]) and the positive condition (mean = 70.57; 95% CI = [65.78, 75.36]). Bonferroni-corrected post-hoc tests reached significance for the comparison between neutral and negative ($p < 0.01$) and positive and negative ($p < 0.05$), but the comparison between neutral and positive failed to reach significance ($p = 0.67$).

In addition to these two main effects, a significant interaction of behaviour \times emotional condition was observed ($F_{(2,99)} = 4.41$; $p < 0.01$; partial $\eta^2 = 0.04$). To disentangle this effect, Bonferroni-corrected post-hoc tests were calculated. For embracing, significant differences between the neutral condition and the negative ($p < 0.01$) and the positive ($p < 0.01$) conditions were observed, indicating a higher absolute LQ in the neutral than in the two emotional conditions. For kissing, a significant difference was observed only for the comparison between the positive and negative condition ($p < 0.01$), indicating a higher absolute LQ in the positive than in the negative condition. For cradling, all Bonferroni-corrected post-hoc tests failed to reach significance.

Social touch: associations between social touch LQs

In order to determine the associations between the LQs for the different forms of social touch, Neyman-Pearson correlation coefficients were calculated (see Table 4). None of the correlation coefficients reached significance (all $ps > 0.37$).

Social touch: association between social touch LQs and motor preferences

In order to determine the associations between the LQs for the different forms of social touch and handedness and footedness, Neyman-Pearson correlation coefficients were calculated (see Table 5). None of the correlation coefficients reached significance (all $ps > 0.09$).

Discussion

In the present study, we investigated laterality of embracing, cradling and kissing, three important forms of social touch in humans. We also assessed handedness and footedness to determine whether laterality in social touch was linked to motor laterality. Furthermore, we tested laterality of social

Table 4. Correlation coefficients between the three forms of social touch.

		Embracing	Cradling	Kissing
Neutral	Embracing	Cradling	0.17	
		Kissing	-0.05	0.02
Positive	Embracing	Cradling	0.06	
		Kissing	-0.07	0.03
Negative	Embracing	Cradling	-0.02	
		Kissing	-0.04	0.09

Asterisks indicate significance at the $p < 0.05$ level.

touch in situations with different emotional valence (neutral, negative and positive) in order to test whether emotional status influences individual side biases.

Laterality of social touch

Based on the published literature, we expected to replicate a general rightward bias for embraces (Packheiser, Rook, et al., 2019; Turnbull et al., 1995) and kisses (Barrett et al., 2006; Güntürkün, 2003; Karim et al., 2017; Ocklenburg & Güntürkün, 2009; van der Kamp & Canal-Bruland, 2011) and a leftward bias for cradling (Almerigi et al., 2002; Dagenbach, Harris, & Fitzgerald, 1988; Fleva & Khan, 2015; Harris & Fitzgerald, 1985; Manning & Denman, 1994; Matheson & Turnbull, 1998; Saling & Tyson, 1981; Salk, 1960; Souza-Godeli, 1996; Turnbull & Lucas, 1991; van der Meer & Husby, 2006; Vauclair & Donnot, 2005).

Unlike most previous studies we determined participants side preferences based on an LQ that was derived from testing each behaviour multiple times and grouped them into three categories: right-preferent, left-preferent and ambilateral. A first interesting finding of the present study was that for all three types of social touch there was a considerably large group of ambilateral individuals (between 20% and 40%). This indicates that on the population level, laterality of social touch might be less consistent than previously thought. Since most other studies did either one-trial testing or grouped

Table 5. Correlation coefficients between the three forms of social touch.

		EHI	WFQ
Neutral	Embracing	0.02	0.01
	Cradling	0.01	0.08
	Kissing	0.01	-0.15
Positive	Embracing	0.004	0.02
	Cradling	-0.09	-0.11
	Kissing	-0.03	-0.17
Negative	Embracing	-0.13	-0.01
	Cradling	0.03	-0.01
	Kissing	-0.03	-0.14

Asterisks indicate significance at the $p < 0.05$ level.

participants according to their LQ with a cut-off of 0 for right-preferent or left-preferent, these ambilateral individuals might have been classified as left- or right-preferent in previous studies. In comparison to social touch, we did not find a single ambilateral individual for handedness in our sample. Thus, laterality of social touch seems to be less consistently left- or rightward than handedness which is consistent with findings for almost all other behavioural asymmetries.

For hugging, we found a significant rightward preference in all three conditions, replicating previous studies (Packheiser, Rook, et al., 2019; Turnbull et al., 1995). Overall, between 52% and 65% of participants showed a rightward preference, making this the most common of the three possible outcomes.

For kissing, we also expected an overall rightward bias. Here, the effect reached significance only for the positive condition, with 46% of participants showing a rightward preference, 21% being ambilateral and 33% showing a leftward preference. This at least partially replicates the published literature. In a previous study on kissing laterality, Güntürkün (2003) observed kisses at public places (e.g., airports, parks or beaches) and found a 2:1 (64.5% to 35.5%) ratio for rightward compared to leftward kisses. It could be speculated that most couples that were assessed in this study were kissing each other in a positive mood, making the positive condition in our study the condition with the highest external validity when comparing our data to such observational studies on kissing. Also, since previous work did not include the ambilateral category, the percentages that we observed in our study could reflect a similar distribution than observed by Güntürkün (2003) if the occurrence of ambilateral individuals in this cohort would be approximated.

For cradling, we were unable to replicate the published literature that generally reports a leftward bias (see Packheiser et al. (2019) for a recent meta-analysis). While we found a considerably large group of individuals with a leftward cradling preference in all three conditions (between 28% and 33%) we still found a significant rightward preference in all three conditions.

We can only speculate why our data show this clear contradiction to the literature. One possible explanation could be that our test participants were psychology students with a mean age of about 24 years instead of actual mothers cradling their own children. Our participants thus might have had little to no experience cradling a child. A major hypothesis explaining cradling lateralization postulates that the dominant arm remains free to pursue more fine-tuned motor tasks (van der Meer & Husby, 2006). If participants have never experienced the necessity of performing these tasks during cradling, the bias should not be present. De Château (1983) found that men that are inexperienced with children have a less pronounced left cradling bias compared to actual fathers with lots of experience supporting this hypothesis. However, van der Meer and Husby (2006) investigated the effect of

experience on cradling bias and also found a leftward cradling bias in inexperienced participants, calling into question if this was truly the case. Another possible explanation would be that the doll failed to evoke the impression of a human child on our participants. For example, Forrester, Davis, Mareschal, Malatesta, and Todd (2019) found that young children show a left cradling bias for a human doll, but a right cradling bias for a primate doll. If the participants in our study perceived the doll not like a human baby but like a non-human object, they might have just handled it with their dominant hand, explaining the rightward bias. It has to be noted however that a schematic face on a proto-face pillow was sufficient to elicit the left cradling bias. Additionally, Packheiser, Schmitz, et al. (2019) found no moderating effect between doll and human cradling with regards to the cradling bias indicating against the idea that the doll had a significant influence on the observed results. Finally, it could have been that our participants were altered in their lateral bias due to the social judgement induced by the observing experimenter. Since our participants were very young, they might have been affected by the idea that they were expected to hold a child correctly possibly changing the direction of the bias.

Motor biases affecting social touch

We found evidence for an effect of motor preferences on the laterality of embracing, but not for cradling and kissing. For embracing, participants with a leftward preference for embracing showed a lower handedness LQ than the other two groups. Thus, left-handedness seems to be linked to a leftward preference when embracing. This is in line with the work of Packheiser, Rook, et al. (2019) who also found a significant association of embracing bias and motor preferences. Not finding an effect for cradling and kissing is also in line with some of the published literature. For example, Forrester et al. (2019) did not find an association of handedness and cradling bias. Similarly, Barrett et al. (2006) did not find a significant difference in handedness between right- and left-kissers as both groups were mostly right-kissers.

Emotive biases affecting social touch

Both the validation study and the analysis of the ratings provided by our participants indicated that our emotion induction was successful and participants immersed in the stories. For the categorical analysis, we found a significant leftward shift in the negative conditions compared to the neutral condition for embracing. There also was a strong trend into the same direction for the positive conditions. This asymmetry was mainly driven by female participants as males did not demonstrate a shift from neutral to emotional conditions. Thus, in line with the findings of Packheiser, Rook, et al. (2019) we

found a leftward shift in the emotional embracing conditions irrespective of valence for females, but not for males. Even though this study did not directly measure any neurophysiological activity, the general shift in LQs towards the left speaks in favour of a right-hemispheric dominance for emotional processing as motor networks in the right hemisphere were most likely influenced by the induction of affect in the study. Such interactions have been demonstrated in humans (Borod, 1993) and non-human species alike (Siniscalchi, Sasso, Pepe, Vallortigara, & Quaranta, 2010) and thus provide a pervasive explanation for the observed results. Especially in infant holding studies, a significant interaction between emotional lateralization in the brain and cradling preference has been found indicating in favour of this hypothesis (Bourne & Todd, 2004; Donnot & Vauclair, 2007; Vauclair & Donnot, 2005). Another explanation is provided by a theory of Forrester et al. (2019) that proposes a right-hemispheric dominance in social interaction and self-directed behaviour as opposed to a left-hemispheric dominance of e.g., object manipulation which has been supported by studies of social behaviour in humans. However, the lack of a shift for male participants rather indicates against this theory, as sex should not affect this bias in social interactions. It could however be the case that this bias is more pronounced in females compared to males and simply was not detected due to a lack of power in male participants.

No effect of the emotional induction was observed for kissing and cradling. However, there was a statistical problem with the kissing and cradling analysis. For both behaviours, there were much more left-preferent individuals than were found for embracing. This might have led to an “averaging out” of potential emotion effects between the two subgroups with positive and negative LQs. We therefore performed a second analysis in which we compared absolute LQs independent of direction between the behaviours and emotion conditions. Here it was found that strongest absolute preference was actually observed for kissing, not embracing.

Moreover, we found a main effect of emotional condition, with the negative condition compared to the neutral and positive showing a reduction of asymmetry. This is in line with a study that showed that stress, a condition that has been linked to negative emotions (Banqueri, Méndez, & Arias, 2017), leads to a reduction of asymmetry for social touch (Suter, Huggenberger, & Schächinger, 2007). In this study, the cradling bias was investigated in two groups of nulliparous females, one that underwent the Cold Pressor Stress Test and another one that was not stressed. In the stressed group, the authors found a reduction of the leftward cradling bias after stress induction. Further research is needed to clarify the effects of stress on kissing and embracing, but since stress has been shown to affect hemispheric asymmetries on multiple levels (Ocklenburg, Korte, Peterburs, Wolf, & Güntürkün, 2016), it is at least conceivable that it also affects embracing and kissing laterality. This would

be in line with the interaction that revealed that the asymmetry reduction in the negative emotion condition was mainly driven by the embracing and kissing data, not by the cradling data (although this data showed a similar non-significant trend on the level of descriptive statistics, see [Figure 3](#)).

Thus, it could be speculated that the reduction of asymmetry in the negative emotion condition could be caused by similar effects, e.g., that imagining an embrace, kiss or cradle with a negative emotional connotation could have induced a stress response that lead to a reduction of asymmetries. However, further studies are needed to test this assumption before any conclusions in this direction can be drawn.

Associations between different forms of social touch

Interestingly, hemispheric asymmetries in the three forms of social touch seem to be largely independent of each other. For the categorical analysis, we found a significant positive correlation between embracing and cradling, but only in the neutral condition. For the LQ analysis, no significant effects were observed. The link between embracing and cradling might be explained by the fact that the arms are more involved in these behaviours. In contrast, kissing laterality mostly involves a head turn. With the exception of embracing, laterality in social touch was also independent of motor laterality, e.g., handedness and footedness. This suggests that in addition to motor preferences like handedness and footedness and sensory preferences like eye and ear preferences (Mandal, Pandey, Singh, & Asthana, 1992), social touch might represent a third, independent category of lateral preferences on the behavioural level. It has to be noted however that correlations between lateral biases in general are rather low and the interpretation of social touch being a novel category should therefore be treated with caution.

Limitations and future directions

This study provided a first step in understanding how asymmetries in prevalent and lateralized social behaviours such as embracing, cradling and kissing are influenced by the emotional context. However, there were some shortcomings in this study which could be improved in future research. First of all, the ratings of the short stories between the validation group and the final sample were identical in their general direction, but shifted positively in the final sample. Here, neutral stories were rated mildly positively and negative stories only marginally negatively. This could have affected the observed results as the underlying emotionality might not have been as neutral or negative as would have been desirable. Given that we replicated the embracing results from our previous study, it is unlikely that the discrepancies in ratings were a major issue in the current experiment. Furthermore, while

we used a field condition in our previous study on embracing (Packheiser, Rook, et al., 2019), no field observation was employed in the present study. To validate the results from this study, both cradling and kissing could be observed in different emotional situations akin to the study of Packheiser, Rook, et al. (2019). Another aspect that should be further explored are cultural differences. Here, we only studied participants from Germany. It has been shown that there are considerable differences in social behaviour between cultures. Mediterranean cultures for example demonstrate a lower distance and a higher amount of tactile contact between people during social interactions compared to people living in Western societies (McDaniel & Andersen, 1998; Shuter, 1977). The least physical contact including social touch is found in Asian cultures (Barnlund, 1989). Regarding differences in the laterality of social behaviour, results have been mixed. Saling and Cooke (1984) investigated cradling preferences in different ethnicities from South Africa and found no alterations in the cradling bias. Karim et al. (2017) also found no evidence that the kissing bias is changed in a sample from Bangladesh. However, Chapelain et al. (2015) found that the laterality of cheek kissing varies between different French cities. Therefore, studies investigating the influence of both motor and emotive biases on social touch should be conducted in different cultures to provide more insight into this unexplored topic.

Conclusion

In conclusion, we could replicate a rightward bias for embracing that was modulated by both motor preferences and emotional condition. Kissing and cradling were not related to motor preferences. In general, the negative emotion condition led to a reduction of individual asymmetries, independent of direction. This cannot be explained in terms of the traditional models of emotional lateralization, e.g., the valence and the right hemisphere model, as they both make predictions about the direction of asymmetries. It is, however, in line with the idea that stress induced by the emotionally negative situations might lead to a reduction of lateral bias of social touch.

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ORCID

Patrick Friedrich  <http://orcid.org/0000-0001-5120-5880>

Sebastian Ocklenburg  <http://orcid.org/0000-0001-5882-3200>

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