

Maintaining social bonds via touching: A cross- cultural study

Julia T. Suvilehto



Maintaining social bonds via touching: A cross-cultural study

Juulia T. Suvilehto

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Touching is the most intimate way of social interaction and also the first way of communicating between the mother and the infant. In non-human primates social touching is also the primary way of maintaining social relationships. The extant research suggests that social relationships also govern the use of social touch in humans, but the role of social touch in human bonding in different reproductive, affiliative, and kinship-based relationships remains unresolved.

This Thesis investigates social touching across different kin-based and affiliative relationships in different cultures. This was done by using Internet-based surveys where participants from Finland, France, Italy, Japan, Russia, and the United Kingdom indicated where they would allow different members of their social network to touch them. Topographical organization of bodily regions triggering sexual arousal in romantic relationships was established in a separate study. Finally, functional Magnetic Resonance Imaging was used to reveal the neural correlates of experiencing and anticipating touch from different individuals.

We found that touch is used in relationship-specific manner. The bodily area where touching was allowed was linearly dependent on the emotional bond with the toucher. Moreover, the results indicate that the use of social touch is culturally universal and culture-specific variation is minimal. In romantic relationships, genitals and chest area had the highest potency for eliciting sexual arousal, but partner's touch to practically any bodily area could elicit significant sexual arousal. Finally, neuroimaging data established that relationship-specific information regarding social touch is represented already in the early sensory cortices.

These findings highlight the central role of social touch in human relationships. Together with earlier work these results suggest that humans do use social touch to establish and maintain social relationships, both in romantic pair bonds and in the wider social network.

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Koskettaminen ihmisten intiimein kanssakäymisen muoto ja ensimmäinen viestintäkanava äidin ja lapsen välillä. Muut kädelliset käyttävät sosiaalista koskettamista sosiaalisten suhteiden ylläpitoon. Sosiaaliset suhteet säätelevät koskettamista myös ihmisillä, mutta sosiaalisen koskettamisen merkitystä erilaisissa sukulaisuuteen, romanttiseen kiintymykseen ja ystävyyteen perustuvissa suhteissa ei tunneta tarkasti.

Tässä väitöskirjassa tutkittiin sosiaalista koskettamisesta erilaisissa ihmissuhteissa useissa eri kulttuureissa. Tutkimus suoritettiin Internet-kyselyinä, joihin vastasi brittiläisiä, italialaisia, japanilaisia, ranskalaisia, suomalaisia ja venäläisiä koehenkilöitä. Tutkittavat merkitsivät ihmiskehon kuviin alueet, joihin he antaisivat sosiaalisen verkostonsa eri jäsenten koskea itseään. Erillisessä tutkimuksessa selvitettiin myös kehon kartat alueista, joiden koskettaminen aiheuttaa seksuaalista kiihottumista. Lisäksi sosiaalisen koskettamisen hermostollista perustaa tutkittiin toiminnallista magneettikuvantamista käyttäen.

Tulokset osoittivat, että kosketusta käytetään eri tavoin eri ihmissuhteissa. Mitä läheisempi kahden henkilön välinen sosiaalinen suhde oli, sitä laajempaa aletta he antoivat toisen koskettaa kehostaan. Sosiaalinen koskettaminen oli myös hyvin samanlaista eri kulttuureissa ja kulttuurien väliset erot olivat pieniä. Erityisesti genitaalien ja rintakehän alueiden koskettaminen koettiin seksuaalisesti kiihottaviksi, mutta puolison kosketus lähes koko kehon alueelle voi olla seksuaalisesti kiihottavaa. Aivokuvantaminen osoitti, että kosketukseen liittyvää sosiaalista tietoa käsitellään jo varhaisilla tuntoaivokuorilla.

Tulokset korostavat sosiaalisen koskettamisen merkitystä ihmissuhteissa. Yhdessä aikaisempien tutkimusten kanssa tulokset osoittavat, että sosiaalista koskettamista käytetään ihmissuhteiden muodostamisessa ja ylläpitämisessä, sekä parisuhteissa että myös laajemmassa sosiaalisessa verkostossa.

Avainsanat sosiaalinen koskettaminen, kosketus, tunneside, sosiaalinen verkosto**ISBN (painettu)** 978-952-60-8263-9**ISBN (pdf)** 978-952-60-8264-6**ISSN (painettu)** 1799-4934**ISSN (pdf)** 1799-4942**Julkaisupaikka** Helsinki**Painopaikka** Helsinki**Vuosi** 2018**Sivumäärä** 160**urn** <http://urn.fi/URN:ISBN:978-952-60-8264-6>

Acknowledgements

When I was around ten years old, my mom defended her thesis. I was told that the other person in the room was called ‘opponent’ (suom. vastaväittäjä, literally ‘counter arguer’) which I found delightful since I was opposed to great many things and had a penchant for quarrelling. For a while I went around telling everyone I’d become a ‘counter arguer’ when I grow up. This went on until I was told that being an opponent not a profession, per se, and in order to become an opponent one has to study hard and defend one’s own thesis. This was enough to dissuade me and I all but forgot about my plans of an academic career. Fast forward to 2013, when I spotted an ad for a doctoral candidate position in a field I’d long been interested in, gathered my courage, and sent in an application. What followed has been a fantastically educational journey full of ups and downs. Now, as I am ready to send my thesis off to the printers, I’d like to take a moment to thank some of the people who have played a role in this.

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Oxford, October 2018

Juulia Suvilehto

Counter arguer in training

Contents

Acknowledgements	1
List of Abbreviations and Symbols	5
List of Publications.....	6
Author's Contribution	7
1. Introduction	9
1.1 Touch processing in the nervous system	9
1.1.1 Discriminatory touch.....	10
1.1.2 The C-tactile system	10
1.1.3 Cortical processing of touch.....	11
1.2 Relationship-specificity of touch	12
1.2.1 Perceptions of social touch.....	12
1.2.2 Social touching behaviour	15
1.2.3 Relational, cognitive, and physiological effects of social touch	16
1.2.4 Touching in a romantic relationship	17
1.3 Social touch in different cultures.....	18
2. Objectives	19
3. Materials and Methods	20
3.1 Subjects.....	20
3.2 On-line data collection	20
3.3 The emBODY tool	21
3.4 Functional Magnetic Resonance Imaging	22
4. Summaries of the studies.....	24
4.1 Topography of social touching depends on emotional bonds between humans.....	24
4.1.1 Aims of the study	24
4.1.2 Methods	24
4.1.3 Results.....	25
4.1.4 Conclusions	29
4.2 Relationship-specific social touching is culturally universal	30
4.2.1 Aims of the study	30

4.2.2	Materials and methods	30
4.2.3	Results.....	30
4.2.4	Conclusions	33
4.3	Topography of Human Erogeous Zones	33
4.3.1	Aims of the study.....	33
4.3.2	Materials and methods	33
4.3.3	Results.....	34
4.3.4	Conclusions	35
4.4	Relationship-specific encoding of social touch in somatosensory and insular cortices.....	36
4.4.1	Aims of the study.....	36
4.4.2	Materials and methods	36
4.4.3	Results.....	37
4.4.4	Conclusions	39
5.	General discussion.....	41
5.1	Patterns of social touch	41
5.1.1	Touch within a romantic partnership	42
5.1.2	The role of pleasantness in social touch.....	42
5.2	Social touch in different cultures.....	43
5.2.1	Similarities in the studied cultures	43
5.2.2	Differences in the studied cultures	43
5.2.3	Why did we find more similarities than differences?	44
5.3	The role of touch in social bonding	45
5.4	Limitations and future directions.....	47
6.	Conclusions	49
	References.....	50

List of Abbreviations and Symbols

ACC	anterior cingulate cortex
Acq.	acquaintance
BA	Brodmann area
EPI	echo-planar imaging
EZM	erogenous zone maps
F	female
FDR	false discovery rate
fMRI	functional magnetic resonance imaging
GLM	general linear model
IC	insular cortex
M	male
MRI	magnetic resonance imaging
MVPA	multi-voxel pattern analysis
OFC	orbitofrontal cortex
rTMS	repetitive transcranial magnetic stimulation
S1	primary somatosensory cortex
S2	secondary somatosensory cortex
SEM	standard error of the mean
SPM	statistical parametric map
TAM	touch area map
TE	echo time
TI	touchability index
TR	repetition time
UK	the United Kingdom
VC	visual cortices

List of Publications

This doctoral dissertation consists of a summary, two journal publications, and two manuscripts under review in scientific journals. Publications are referred to in the text by their numerals

- 1.** Suvilehto, J. T., Glerean, E., Dunbar, R. I. M., Hari, R., & Nummenmaa, L. 2015. Topography of social touching depends on emotional bonds between humans. *Proceedings of the National Academy of Sciences*, 112, 45, 13811–13816. <http://doi.org/10.1073/pnas.1519231112>
- 2.** Suvilehto, J. T., Nummenmaa, L., Glerean, E., Harada, T. Dunbar, R. I. M., Hari, R., Turner, R., Sadato, N., Kitada, R. Relationship-specific social touching is culturally universal. Submitted to the Proceedings of the Royal Society B: Biological Sciences in the year 2018.
- 3.** Nummenmaa, L., Suvilehto, J. T., Glerean, E., Santtila, P., & Hietanen, J. K. 2016. Topography of Human Erogenous Zones. *Archives of Sexual Behavior*, 45, 5, 1–10. <http://doi.org/10.1007/s10508-016-0745-z>
- 4.** Suvilehto, J. T., Renvall, V., Nummenmaa, L. Relationship-specific encoding of social touch in somatosensory and insular cortices. Submitted to the Journal of Neuroscience in the year 2018.

Author's Contribution

Study I: Topography of social touching depends on emotional bonds between humans

The candidate contributed to study design, acquired and analysed the data, and wrote the manuscript. Assistance in data collection and data analysis was provided by E. Glerean. Valuable input for the experimental design and the manuscript was provided by all co-authors.

Study II: Relationship-specific social touching is culturally universal

The candidate contributed to study design, acquired and analysed the data, and wrote the manuscript. The candidate wrote the manuscript in close collaboration with R. Kitada. Valuable input for the manuscript was provided by all co-authors.

Study III: Topography of Human Erogenous Zones

The candidate collected the data and contributed to the data analysis and the writing of the manuscript.

Study IV: Relationship-specific encoding of social touch in somatosensory and insular cortices

The candidate contributed to experimental design, acquired and analysed the data, and wrote the manuscript. Assistance for designing the experiment was received from V. Renvall and L. Nummenmaa. Assistance in data collection was received from V. Renvall. Valuable input for the manuscript was provided by all co-authors.

1. Introduction

Social touch has a rich evolutionary history, with many of our non-human primate relatives devoting up to 20% of their waking hours grooming one another (Lehmann, Korstjens, & Dunbar, 2007). This is done for hygiene reasons, but also to service social relationships within the group (Dunbar, 2010). As a result, primates, unlike many other vertebrates, have non-reproductive bonds ('friendships', see Silk, 2002) that are stable over time (Shultz & Dunbar, 2007).

Humans have taken this a step further. Humans have broad social networks, with the average number of members of a person's active social network at around 100 (Hill & Dunbar, 2003; Roberts, Dunbar, Pollet, & Kuppens, 2009). This network consists of both kin (relatives) and non-kin (friends, acquaintances) members (Roberts et al., 2009), with differing amounts of importance to (or closeness with) the individual (Hill & Dunbar, 2003; Roberts et al., 2009).

These relationships require active maintenance. While non-human primates use grooming for servicing social relationships, humans have evolved to use language as a tool for communication and social bonding (Dunbar, 1993). Although language is a prevalent method for interpersonal contact in humans, social touch still plays a prominent role.

In some human relationships, touching is socially acceptable and widely used. For example, romantic couples engage in touching. Touching is also the first mode of communication between a parent and a baby. In dyadic relationships between two adults who are not romantically or sexually linked, the role of touch is still important. However, touch in these non-romantic relationships has remained elusive.

In this thesis, I show that social touch plays a major role in the establishment and maintenance of a multitude of affiliative bonds in humans. I do this by inspecting how and why different people are touched (Study I), the cultural variation in social touch in different cultures (Studies I and II), the use of touch in sexual intercourse (Study III) and the neural correlates of social touch as a function of the toucher (Study IV).

1.1 Touch processing in the nervous system

The skin is our largest organ. While any sensation arising from contact on the skin is often thought as 'touch', skin has several different sensory receptor types. There are specialised receptors and pathways for perceiving and processing touch (mechanical), temperature (thermal), pain (nociceptive) and itch (pruritic) stimuli. For the purposes of this thesis we will mainly focus on mechanical stimuli. Touch, in the context of this thesis, is defined as non-painful mechanical stimuli (Zimmerman, Bai, & Ginty, 2014).

Mammals have two types of skin: hairy (non-glabrous) and non-hairy (glabrous). Most of the skin in humans is covered in short, non-pigmented vellus hairs and/or long, thick, pigmented terminal hairs. This is called non-glabrous skin. In contrast, the skin in for example the soles of the feet, palms of the hands and the lips does not contain any type of hairs. This skin is called glabrous. This distinction is relevant, because some touch receptors (discussed in more detail in Sections 1.1.1 and 1.1.2) only occur in glabrous and some in non-glabrous skin.

1.1.1 Discriminatory touch

To handle objects of different shapes and sizes, we need to be able to detect their texture, slip, vibration, and pressure. Such discriminative touch is supported by a number of touch receptors, jointly called low-threshold mechanoreceptors (LTMRs). LTMRs are the sole mediator of human discriminative tactile sensibility (McGlone, Vallbo, Olausson, Löken, & Wessberg, 2007).

There are a number of different LTMRs in the skin, which help us to detect different properties of a stimulus. The sensation of touch originates from the contact with a stimulus within the receptive field of a specialised mechanoreceptor. This causes the relevant afferent (i.e. a nerve transmitting information from the periphery towards the central nervous system) to transmit a signal. A mechanoreceptive afferent can encode multiple features of the tactile stimulus. When several afferents are activated together, this can give rise to distinct percepts, such as the feeling of a gentle breeze on our skin (Abraira & Ginty, 2013).

LTMRs are innervated by myelinated A β -afferents. These are very fast neurons, with conduction velocities between 16-100 m/s (Abraira & Ginty, 2013; Buchthal & Rosenfalck, 1966; Knibestöl, 1975). The fast conduction velocity is necessary for handling objects without breaking them. LTMRs are not uniformly distributed around the body. Densely innervated locations include fingertips and the face, whereas the back has significantly fewer mechanoreceptors. This contributes to different tactile detection thresholds across sites.

1.1.2 The C-tactile system

The fast myelinated A-fibres encode discriminative information about a tactile stimulus but they only make up around 10-25% of afferent nerves (Griffin, McArthur, & Polydefkis, 2001; McGlone, Wessberg, & Olausson, 2014). The majority of afferents are unmyelinated or thinly myelinated C-afferents. Most C-afferents are thought to respond to nociceptive stimuli, such as heat, cold, or mechanical noxious stimulus (Abraira & Ginty, 2013). However, there is a group of C-afferents, called C-tactile (CT) afferents, that respond to stimuli below nociceptive range (Vallbo, Olausson, Wessberg, & Norrsell, 1993). These afferents do not exist on the glabrous skin (Vallbo, Olausson, & Wessberg, 1999). CT afferents, being small and unmyelinated, have a much lower conduction velocity (approx. 0.9 m/s, Vallbo et al., 1999) than the A β -afferents.

C-fibres contribute to processing of affective features of touch, responding selectively to slow, stroking-type touch (Vallbo et al., 1993). The optimal speed for CT afferent receptive field is around 1-10 cm/s, which is also the speed that is considered the most

pleasant by people (Y.-S. Lee et al., 2018; Löken, Wessberg, Morrison, McGlone, & Olausson, 2009). CT afferents also respond most vigorously to stroking at skin temperature (Ackerley et al., 2014). Due to these features, and the slowness of the signaling, it has been suggested that CT afferents would be relevant for the affective processing of touch (Morrison, Löken, & Olausson, 2010).

These afferents were discovered in human relatively recently, most likely because it is impossible to stimulate them without also stimulating A β afferents. Detecting them was possible due to a technique called microneurography, which allows recording activity from individual afferent nerves in awake humans (Vallbo & Hagbarth, 1968; Vallbo et al., 1993). Further proof of the function of these fibres was provided by a subject, G. L., who had a selective loss of large-diameter myelinated afferents. G.L. was able to detect soft, stroking touch on the hairy skin (i.e. an area with CT-receptors), but not on the glabrous skin of the palm (Olausson et al., 2002).

1.1.3 Cortical processing of touch

Discriminative and emotional aspects of tactile stimuli are processed in different parts of the brain (Francis et al., 1999). Discriminative touch is transmitted via the thalamus to the primary somatosensory cortex (S1). S1 comprises four cytoarchitectonic areas, the Brodmann areas 1, 2, 3a and 3b (BA1, BA2, BA3a, BA3b) (Kaas, 2004). These areas constitute a processing hierarchy, with areas 3b and 3a acting as true primary somatosensory processing areas and areas 1 and 2 as secondary areas (Eskenasy & Clarke, 2000). For example, while area BA3b responds to experienced tactile stimuli, area 2 is also active when observing others handle objects (Gazzola & Keysers, 2009). From S1, the signal is transmitted to secondary somatosensory cortex (S2), where it is integrated with input from other sensory modalities (Keysers, Kaas, & Gazzola, 2010).

Studies with the neuropathy patient G. L. have confirmed that the CT afferents project to different cortical areas than A β afferents. While neurotypical controls showed clear activation on S1, S2, and insular cortex in response to CT-optimal soft brush stroking, patient G.L. shows no activation in S1 or S2. In contrast, posterior insula responded to the stroking both in controls and in G. L. showing that CT-afferents would project directly to IC (Olausson et al., 2002).

Much less is known about the cortical processing of the social and affective features of non-painful touch. Out of the different affective dimensions, the pleasantness of touch has been the most studied. Pleasant touch causes activity changes in orbitofrontal cortex (Francis et al., 1999; McCabe, Rolls, Bilderbeck, & McGlone, 2008), anterior cingulate cortex (Case et al., 2016; Rolls et al., 2003) and superior temporal sulcus (Davidovic, Bjornsdotter, Olausson, & Bjornsdotter, 2016). While different studies have found different cortical correlates for the pleasantness of touch, these findings are not mutually exclusive since the experimental set-ups are slightly different from experiment to experiment.

S1 is not typically involved in the processing of affective dimensions of touch. For example, one TMS study found that inhibitory repetitive transcranial magnetic stimulation (rTMS) over S1 did not alter the experienced pleasantness of touch (Case et al., 2016). However, S1 might still be involved in the processing of social features of the touch (Gazzola et al., 2012; Scheele et al., 2014). In one fMRI study, male subjects were led to believe that they were touched by an attractive female or a less attractive male

confederate, when in reality they were always touched by the same experimenter blind to the experimental condition. The cortical responses to these two actors differed significantly in S1, specifically in BA1 and BA2 (Gazzola et al., 2012). These results were replicated by Scheele et al. (2014). Also OFC was sensitive to the visual sex (Gazzola et al., 2012). Thus, while the cortical processing of discriminative touch is fairly well understood current understanding of the processing of affective and social features of touch is still quite poorly understood.

1.2 Relationship-specificity of touch

In everyday social interaction, you likely encounter different types of social touch. These are intentional touches, often conducted by hand. These touches can be ‘*simple*’, meaning brief, intentional contact to a restricted area, such as tapping a person’s shoulder to get their attention. They can be ‘*protracted*’, when a contact is extended and often combined with pressure, like a hug. Intentional touch can also be ‘*dynamic*’, i.e. combining sustained contact and movement, like stroking (Morrison et al., 2010). All of these different types of touches can have different meanings, and that meaning can change depending on the relationship between the toucher and the person being touched.

Touch can convey a powerful message¹. Imagine you’re at a pub, and your partner wraps their hand around you from the back. You lean in contentedly, and then you realise that the hand belongs to a stranger. The touch you enjoyed just a moment ago suddenly turns unpleasant and unwelcome. It is thus clear that many aspects of touch depend on the identity of the toucher.

1.2.1 Perceptions of social touch

Like most other forms of communication, the act of one person (the sender) intentionally touching another person (the receiver) can be interpreted as a message. Changing any of these three features (the sender, the touch, the receiver) can change the message. For example, the sex of the sender (Gazzola et al., 2012; Heslin & Alper, 1983), the sex of the touch recipient (Heslin & Alper, 1983; Nguyen, Heslin, & Nguyen, 1975), the relationship between the toucher and the person being touched (Heslin & Alper, 1983; Jones & Yarbrough, 1985; Thompson & Hampton, 2011), the ages of the interactants (Harrison-Speake & Willis, 1995), the type of touch used (Burgoon & Newton, 1991; Hertenstein, Holmes, McCullough, & Keltner, 2009; Heslin & Alper, 1983; Kirsch et al., 2018; Nguyen et al., 1975) and the location where the touch is applied (Nguyen et al., 1975) can all impact the inferred message.

These messages are quite well understood in naturalistic interaction (Jones & Yarbrough, 1985). While naturally occurring touches are accompanied by contextual cues, some complex messages can be understood even when stripped of contextual cues (Hertenstein et al., 2009; Thompson & Hampton, 2011). For example, discrete emotions can be communicated via touch even in the absence of any visual cues

¹ Touching can sometimes be unintentional. For example, exiting a crowded bus you might brush against people as you squeeze through them. Unintentional touches like these do not, by definition, convey any intentional messages. For the purposes of this Thesis, we will be always talking about intentional touch.

(Hertenstein et al., 2009), but the types of touches used to communicate these emotions depends on whether the toucher and the person being touched are strangers or a romantic couple (Thompson & Hampton, 2011).

Table 1. Categories of touch according to Heslin & Alper (1983). An example for each type of touch is presented in the third column, as well as tentative information about for whom this type of touch is acceptable or not acceptable

Category #	Type of touch*	Example of this type of touch	Acceptable for	Not acceptable for
1	functional professional	A medical examination (Heslin & Alper, 1983; Schroeder, Fishbach, Schein, & Gray, 2017)	Professionals (e.g. medical providers, security personnel) (Heslin & Alper, 1983; Schroeder et al., 2017)	Not well known
2	social polite†	A handshake (Heslin & Alper, 1983)	Most people, including strangers (Jones & Yarbrough, 1985)	Acceptable for most people (Jones & Yarbrough, 1985)
3	friendship warmth	A hug (Forsell & Åström, 2012)	Not well known	Not well known
4	love intimacy	Stroking the face (Aznar & Tenenbaum, 2016; Nguyen et al., 1975)	Sexual intimates and close friends (Jones & Yarbrough, 1985) children (Aznar & Tenenbaum, 2016)	Less common in non-romantic male-male pairs (Jones & Yarbrough, 1985)
5	sexual arousal or desire	Rubbing breasts (Curtis, Eddy, Ashdown, & Feder, 2012), stroking (Kirsch et al., 2018; Nguyen et al., 1975)	Sexual partner	Most other people, for example same sex friends (Heslin & Alper, 1983) and co-workers (J. W. Lee & Guerrero, 2001)

* according to (Heslin & Alper, 1983)

† also called 'ritualistic touch'

While the number of potential messages conveyed by touch is large, attempts at categorising have been made. One such categorisation is by Heslin & Alper (1983), who divide touches into five categories based on the relational messages they convey (presented in Table 1). They propose that people are most uneasy about touches in the friendship/warmth category, because there is a possibility that these would be interpreted as conveying love or sexual interest.

These messages and their interpretations are highly relationship-dependent: not all messages are socially acceptable in all relationships (see also Table 1). Consequently, there are relationship-specific expectations concerning where and why touching is appropriate. Touches, which are not congruent with these relationship-specific expectations, are experienced as inappropriate. For example, a touch indicating sexual attraction is considered inappropriate when coming from a person the touch recipient is not sexually interested in, such as a co-worker (J. W. Lee & Guerrero, 2001) or a platonic friend (Heslin & Alper, 1983). More generally, Heslin & Alper (1983) suggest that touch, which conveys a message not congruent with the touch recipient's view of the relationship, can be experienced as uncomfortable (Figure 1).

Many of the relational messages conveyed by touch are straightforward. For example, slow stroking touch is interpreted as loving, sexual, and pleasant (Kirsch et al., 2018; Nguyen et al., 1975). Such meanings are conveyed even in the absence of contextual

cues (Kirsch et al., 2018). Other types of action, such as a hug or a kiss, are interpreted as very intense expressions of affection when used in the context of a friendship (Floyd, 1997). These meanings tied to different types of touches can impact the way a touch is interpreted.

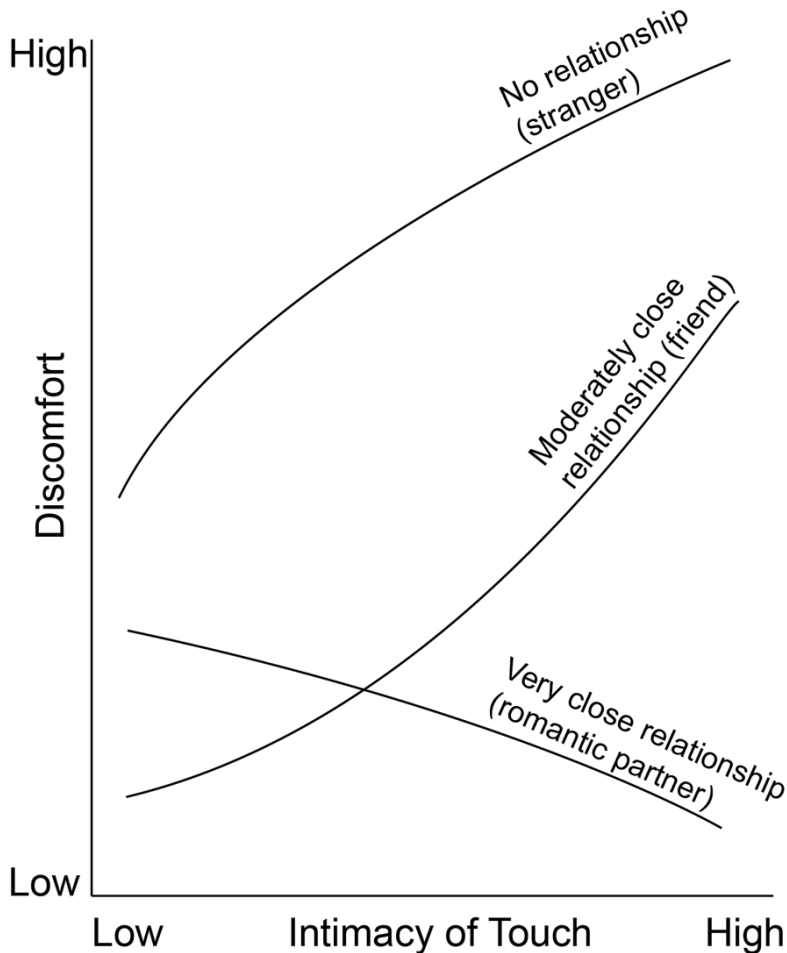


Figure 1. A theoretical model of affective responses to different types of touch by different members of the social network. Figure adapted from (Heslin & Alper, 1983)

This type of signalling by touch can also convey relational information about the dyad to observers. For example, couples engaged in touch are perceived as more close than couples not engaging in social touch (Kleinke, Meeker, & La Fong, 1974). Indeed, merely seeing a touch from the third person perspective can impact how people literally see a situation, i.e. modify the eye movement patterns (Schirmer, Ng, & Ebstein, 2018).

Type of the dyadic relationship impacts the bodily areas where people touch and are touched by people in their social networks (Barnlund, 1975; Jourard, 1966; Rosenfeld, Kartus, & Ray, 1976). This might be partially due to the fact that the meaning of touch can also depend on the body area that is touched. For example, a touch by the romantic partner on the forehead can be seen as conveying warmth/love whereas a touch on the

chest is interpreted as a sign of sexual desire (Nguyen et al., 1975). The topographies of acceptable touch, i.e. where touching is acceptable, have been inspected with respect to friends (Barnlund, 1975; Heslin, Nguyen, & Nguyen, 1983; Jourard, 1966; Rosenfeld et al., 1976; Tomita, 2008), parents (Barnlund, 1975; Jourard, 1966; Rosenfeld et al., 1976), and strangers (Heslin et al., 1983). However, the topographies are not known for a number of different social relationships, such as other family members or acquaintances.

To summarise, the messages sent by touching are highly context and relationship-specific. It is known that some types of messages are clearly out of bounds for some types of relationships, such as the touches indicating sexual interest in a co-worker. However, there has not been a thorough investigation of the appropriateness of different touches in the multitude of relationships that comprise our social networks.

1.2.2 Social touching behaviour

Three methods have been used to measure real-life touching behaviour: observations, real-time reporting (log) methods, and recall-based methods (Thayer, 1986). They can all provide different information about touching behaviour in real life scenarios.

Observations typically take place in a public space where researchers can either code in real-time (Dibiase & Gunnoe, 2004; Guerrero & Andersen, 1991, 1994; J. A. Hall, 1996; J. A. Hall & Veccia, 1990; Heslin & Boss, 1980; Major, Schmidlin, & Williams, 1990; McDaniel & Andersen, 1998; Willis & Briggs, 1992; Willis & Dodds, 1998; Willis & Hoffman, 1975) or record (Burgoon & Le Poire, 1999; Ferber, Feldman, & Makhoul, 2008; Remland, Jones, & Brinkman, 1991, 1995) the touching behaviour. Observational studies tend to try and categorise differences in touch frequencies or types with respect to different groups of people. For example, touching has been found to occur relatively infrequently, in around 9%-20% of interactions (J. A. Hall & Veccia, 1990; Remland et al., 1991, 1995). Dibiase & Gunnoe (2004) found that men engage in more hand-touches whereas women engage in more non-hand touches. Other studies have found that women are more likely to initiate touch while there is no difference in touch receipt between the genders (Willis & Rinck, 1983).

Recall-based methods ask subjects to report, for example, which touch behaviours they have engaged in in the past year (Jourard, 1966) or in the past in general (Barnlund, 1975; Jourard & Rubin, 1968). Recall-based studies show that the areas in which participants reported being touched by and touching a particular person (for example a mother) are strongly correlated (Barnlund, 1975; Jourard, 1966; Jourard & Rubin, 1968). There is also weak support for this from the log methods studies, where it was found that individuals, who initiate more touches, also receive more touches (Jones, 1986). Both of these results emphasize touching as a reciprocal mode of communication, where touching and being touched is tightly linked.

Log methods require individuals to keep track of all of the touches they are a part of within a particular time frame. Jones & Yarbrough (1985) found that in their sample, most naturally occurring touches could be categorised to convey one of 12 meanings (support, appreciation, inclusion, sexual interest or intent, affection, playful affection, playful aggression, compliance, attention-getting, announcing a response, departure, and greeting), and that many of the meanings only arise in particular relationships. For example, touches signalling inclusion mainly occurred between romantic partners and

close friends whereas greeting touches occurred in all relationships (Jones & Yarbrough, 1985).

All of these three methods have distinctive drawbacks. First, observations allow for a diverse subject pool but severely limit the potential contexts, which is problematic since touch behaviour is modulated by the setting (Major et al., 1990; Willis & Rinck, 1983). Second, recall-based methods are particularly susceptible to different kinds of memory-related biases, depending on the recall period, which may result in the responses not describing actual behaviour (Bolger, Davis, & Rafaeli, 2003). Third, while log methods give potentially the most thorough view of touching behaviour, they require highly motivated participants limiting the potential subject pool and just keeping the log may interfere with subjects' actual touching behaviour (Wheeler & Reis, 1991), potentially biasing the results. These challenges are particularly relevant when considering touch behaviour in diverse cultures, which is discussed in Section 1.3.

1.2.3 Relational, cognitive, and physiological effects of social touch

Touching and being touched can feel extremely good (Tricoli, Croy, Olausson, & Sailer, 2017). In fact, some research suggests that we are hard-wired to touch. Another person's skin is perceived as more pleasant than our own (Gentsch, Panagiotopoulou, & Fotopoulou, 2015; Guest et al., 2009), possibly driving the wish to touch. Moreover, being touched is even more pleasant than touching (Tricoli et al., 2017).

Pleasantness of touch is highest when the touch is done at skin temperature (Ackerley et al., 2014) and at CT-optimal speeds (Löken et al., 2009). CT-optimal touch is consistently rated as more pleasant than non-CT optimal touch across different age groups (Croy, Sehlstedt, Wasling, Ackerley, & Olausson, 2017; Sehlstedt et al., 2016). Indeed, when people are told to stroke another human, they do so spontaneously at CT-optimal speeds (Croy et al., 2015). The perceived pleasantness of touch is also linked with the identity of the toucher, even when there is no difference in the tactile input (Gazzola et al., 2012; Nummenmaa, Tuominen, et al., 2016). The drive to be touched is so strong that it can even impact the perception of time (Ogden, Moore, Redfern, & McGlone, 2015).

In addition to eliciting pleasant sensations, social touching can have causal behavioural, psychological, physical, and relational effects on the person being touched (Jakubiak & Feeney, 2016b). Social touch can impact compliance and pro-social behaviour. For example, brief touch increases the tips given to a waitress (Crusco & Wetzel, 1984), improves interpersonal evaluations (Erceau & Guéguen, 2007; Fisher, Rytting, & Heslin, 1976; Hornik, 1992), enhances compliance (Guéguen, 2004), and pro-sociality (Kleinke, 1977). This effect has been named 'Midas touch' by Crusco and Wetzel (1984). A meta-analysis on the impact of social touch on compliance shows that the effect size seems to be relatively small, but consistent (Segrin, 1993); the impact of touch on compliance is also stronger when the person being touched notices the touch (Joule & Guéguen, 2007).

Both laboratory studies (Ditzen et al., 2007; Grewen, Anderson, Girdler, & Light, 2003) and intervention studies (Floyd et al., 2009; Holt-Lunstad, Birmingham, & Light, 2008) show that social touch can buffer stress. Similar benefits can be obtained just by imagining receiving supportive touch (Jakubiak & Feeney, 2016c) and this effect is stronger when the toucher is one's partner (Coan, Schaefer, & Davidson, 2006).

Similarly, holding the partner's (but not a stranger's) hand has an analgesic effect (Goldstein, Shamay-Tsoory, Yellinek, & Weissman-Fogel, 2016). Moreover, non-social CT-optimal touch (brushing with a soft brush) can alleviate physical (Liljencrantz et al., 2017) and social (von Mohr, Kirsch, & Fotopoulou, 2017) pain.

Interpersonal touch can also have beneficial effects on somatic health. Touching elderly patients when encouraging them to eat can cause them to ingest more nutrition (Eaton, Mitchell-Bonair, & Friedmann, 1986). In an interesting study, Cohen et al. (2015) tracked the number of hugs the subjects received and then subjected them to a common cold infection. The subjects who had reported receiving hugs more frequently had a lower risk of infection than those who received less hugs. It is not clear whether these health effects are a direct result of the touch or whether touch serves as an indicator of strong social relationships, which in turn are linked to positive health outcomes (Jakubiak & Feeney, 2016b; Sbarra & Coan, 2017).

1.2.4 Touching in a romantic relationship

Romantic pair bond is a special type of relationship. Touch in romantic pairs has been studied much more than in other types of relationships. Consequently, the use and effects of social touch in a romantic relationship are much better known than use and effects of social touch in other types of relationships. Touching in romantic relationships is not stable over time but instead is modulated as a function of the stage of the relationship (Emmers & Dindia, 1995; Guerrero & Andersen, 1991). This might be due to the perception of touches changing as a function of the relationship stage (Hanzal, Segrin, & Dorros, 2008). For example, unmarried women experience touches from their romantic partner as less pleasant and less loving than married women (Hanzal et al., 2008).

In romantic relationships touch is used to express affection (Hertenstein, Verkamp, Kerestes, & Holmes, 2006). There is a well-established connection between relationship satisfaction and physical affection (touching) between partners (Gulledge, Gulledge, & Stahmann, 2003; Muise, Giang, & Impett, 2014). This effect is found in both older and younger couples and in different cultures (Heiman et al., 2011; Kontula, 2016). The type of touch does not seem to be important: kissing, hugging, cuddling and back rubs all correlate with relationship satisfaction (Gulledge et al., 2003).

Touching does not have to be spontaneous to improve relationship satisfaction. A simple experimental intervention, where participants were told to kiss their partners more often, also increased the relationship satisfaction in that group (Floyd et al., 2009). This suggests that social touch is not merely a marker of a good relationship, but rather contributes to it.

The causal mechanisms via which touch impacts relationship satisfaction remains unknown. Jakubiak and Feeney (2016b) outline possible links between relationship satisfaction ('relational well-being') and touch receipt. They propose that receiving affectionate touch can promote feelings of attachment and acceptance, which in turn would make the person who was touched to view their relationship more favourably (Jakubiak & Feeney, 2016b).

Affectionate touch is also used for modulating emotional states within the relationship. Affectionate touch by one's partner can, for example, reduce feelings of jealousy (Kim, Feeney, & Jakubiak, 2017), potentially via enhancing felt security (Jakubiak &

Feeney, 2016a). Touch in a romantic relationship is known to also increase trust in the relationship (Nelson & Geher, 2007). More generally, touch has been implicated in playing a role in the emotion regulation within a couple (Debrot, Schoebi, Perrez, & Horn, 2013).

Touching can also be used for eliciting sexual arousal. This is primarily restricted to short- and long-term prospectively reproductive relationships. Touching is widely used as a sexual initiation cue and it is very reliably recognised as such (Curtis et al., 2012). In particular CT-optimal touching speeds are interpreted as erotic (Jönsson et al., 2015) or as conveying arousal, lust, and desire (Kirsch et al., 2018). However, some types of touch, specifically cuddling, can be conceptually perceived as non-sexual and still experienced as sexual (Van Anders, Edelman, Wade, & Samples-Steele, 2013). Moreover, issues with sex (specifically female sexual problems) can also impact attitudes toward non-sexual touch (Rancourt, MacKinnon, Snowball, & Rosen, 2016). These findings highlight the relevance of investigating both non-sexual and sexual touching in romantic couples.

1.3 Social touch in different cultures

Cultures have classically been divided into ‘contact’ and ‘non-contact’ cultures (E. T. Hall, 1969) based on the differences in social touching. A traveller trying to navigate the appropriate greetings in Northern and Southern Europe or Asia would likely find this a reasonable distinction. And indeed, there is some support to this view.

Observational studies have found a difference in frequency of social touching across different cultures. Remland et al. (1995) found that Greek and Italian dyads used social touch more frequently than English, French, and Dutch dyads in public places. The proportion of Greeks using social touch was 21%, the Dutch were at 4%, with Italians, Irish, British, Scottish, and French between these two extremes (Remland et al., 1995). Some studies also suggest that different cultures use different *types* of touch (Dibiase & Gunnoe, 2004; Regan, Jerry, Narvaez, & Johnson, 1999) or touch in more body areas as a part of ritualistic leave-taking (McDaniel & Andersen, 1998). Jourard (1966) observed the frequency of touches at a cafe table in four different countries. He found that people in Puerto Rico and Paris touched more frequently than people in the UK or continental US (although the sample size seems to have been diminutive).

Topographies (where people touch each other) may also vary across cultures. In a self-report study Barnlund (Barnlund, 1975) compared touch zones in Japanese and American students. He found that, while America has been called a non-contact culture, American subjects reported more comfort with being touched by their parents or friends (Barnlund, 1975).

However, judging cultural differences in touch behaviour is not easy, mostly because reliably studying touching behaviour is difficult in general (see Section 1.2.2). The cross-cultural data mainly stem from observations in public places and most of these studies have modest sample sizes per culture, resulting in low statistical power. All of these factors make the aforementioned results less reliable and less generalisable. The methodological challenges limit the conclusions that can be drawn from the existing cultural comparisons and highlight the need for more comprehensive comparisons of touch in different cultures.

2. Objectives

Earlier attempts at quantifying the relationship-specificity of touch have yielded inconclusive results. Typically, they have included only some relationships (e.g. Heslin & Alper, 1983; Jourard, 1966) or been conducted in limited, mainly public, settings (e.g. Dibiase & Gunnoe, 2004; Guerrero & Andersen, 1994). These are serious shortcomings, since a typical social network includes many individuals with different formal relationships (Dunbar, 2018; Roberts et al., 2009) and social touching is known to vary as a function of the setting (Major et al., 1990; Willis & Rinck, 1983).

Moreover, possible cultural differences in social touch are poorly understood. Studies covering multiple settings and relationships (i.e. using log or recall based methods) generally only use a single-culture sample (Jones, 1986; Willis & Rinck, 1983). Observational studies, where several cultures were included, have used relatively uninformative metrics such as number of dyads using touch in a particular public setting (Remland et al., 1995). These studies thus yield an incomplete picture on how social touch is used in different relationships and in different cultures.

Touching is also abundant in romantic relationships. One reason social touch is used particularly in pair bonds is for eliciting sexual arousal. While it seems that numerous bodily areas may have capability for triggering sexual arousal upon touch (Turnbull, Lovett, Chaldecott, & Lucas, 2014), it is not clear whether these differ when touching oneself and being touched by a partner.

In this thesis, I present two studies investigating the relationship-specificity and cultural variability of the use of social touch. Furthermore, I present one study inspecting the neural correlates of social touch and one study investigating sexually arousing touch. The aim of this thesis was to quantitatively inspect peoples' perceptions of the use of social touch in their social networks. We also investigated the cultural variation in the relationship-specific social touching allowances.

The specific aims of the individual studies were:

- i. To establish relationship-wise topographies of acceptable social touch over the range of an individual's social network and describe any cultural variation in these (Study I).
- ii. To describe the cultural variation in relationship-specific touching allowances between West European (British) and East Asian (Japanese) cultures (Study II).
- iii. To quantify the difference in the use of touch for sexual pleasure during masturbation and sex with partner (Study III).
- iv. To investigate the neural basis of encoding relationship-specific aspects of affective touch (Study IV).

3. Materials and Methods

3.1 Subjects

The subjects in the studies were recruited mainly via online advertisements. In Studies I and III, where the data were collected using an online tool, the subjects in the Finnish, Russian, Italian, and French samples were collected using advertisements posted to different discussion forums, on social media, and mailing lists. The British sample (Studies I and II) and the Japanese sample (Study II) were collected using incentivised survey data collection services, Maximiles and MyVoice Communications, respectively. The numbers of subjects and their gender and age distributions are presented in Table 2. The subjects in Study IV were 10 romantic couples who had been going steady for at least 6 months prior to scanning. All subjects were healthy, right-handed, and with normal or corrected-to-normal vision. Conventional fMRI exclusion criteria were applied. The subjects in Studies I - III gave informed consent online prior to starting the experiment, while the subjects in Study IV gave written informed consent at the beginning of the scanning session.

Table 2. Participant statistics for each study and sample

	Study I, Exp. 1	Study I, Exp. 2					Study II		Study III	Study IV
Study type	On-line	On-line					On-line		On-line	fMRI
Culture	Finnish	Finnish	French	Italian	Rus- sian	British	British	Japa- nese	Finnish	Finnish
Sample size	91 61 F 30 M	194 159 F 35 M	111 90 F 21 M	462 360 F 102 M	56 45 F 11 M	545 229 F 316 M	386 172 F 214 M	254 121 F 133 M	704 528 F 176 M	19 9 F 10 M
Age M (SD) in years	28.2 (9.2)	31.9 (11.7)	31.1 (14.0)	32.5 (22.3)	26.3 (10.6)	44.7 (12.9)	46.0 (12.6)	40.1 (14.6)	26 (6.5)	29 (8)

3.2 On-line data collection

The data in Studies I-III were collected using in-house on-line survey tools. These tools were web browser based, which meant that the subjects were able to fill in the questionnaires from their own homes, using their own devices. All of the studies included background questions and multiple choice, Likert-like scales. The background questions included age, sex, weight, height, and education level of the respondent. The participants also included information about their social network. In Studies I and II the participants filled in information about their whole social network (described in more detail below), while in Study III they only answered questions about their romantic relationship.

For mapping the social network in Studies I and II, the participants were presented with a list of 13 candidate members, [partner, mother, father, sister, brother, aunt, uncle, female cousin, male cousin, female friend, male friend, female acquaintance, male acquaintance], and they reported whether they had at least one exemplar of this formal relationship (e.g. at least one female cousin) in their social network. In addition to these 13 members, we also added a male and a female stranger to the network. The subjects were then asked to provide background information about the members of their social network and strangers. The background information included the approximate ages (set to subject's own age for strangers), time since last seeing them (set to 0 for strangers), how strong an emotional bond they felt with that person, and how pleasant they thought a touch from this person would feel.

Study III also required participants to estimate their own attractiveness as well as to fill in the Sell Assessment of Sexual Orientation (Sell, 1996) and Derogatis Sexual Functioning Inventory (Derogatis & Melisaratos, 1979). Participants, who reported being in a relationship also completed a questionnaire on relationship quality (Fletcher, Simpson, & Thomas, 2000).

3.3 The emBODY tool

In all of the studies, data were also recorded using the emBODY colouring tool (Nummenmaa, Glerean, Hari, & Hietanen, 2014). This tool consists of a screen with a body shown from the front and back (Figure 2a) and a text prompt describing the task. The subjects can colour any area of the screen using their mouse or a touch pad.

In Studies I, II, and IV the task was to indicate areas that are acceptable to touch in different relationships. After completing background questions and before being shown the emBODY screen, the subjects were instructed in the colouring task. The subjects were told to colour in all areas of the body where they would feel comfortable with a particular member of their social network (such as their sister) touching them in different everyday situations. In Studies I and II the subjects coloured relationship-specific touch allowance maps for all members of their social network. In Study IV, the subjects only provided the touch maps for their partner and a male and a female stranger. An example of the subject-wise touch maps is shown in Figure 2b.

In Study III, the subjects indicated areas whose touching they found sexually arousing while masturbating or having sex with a partner and the areas they assumed a member of the opposite sex would find sexually arousing. The tool was otherwise similar, but the background image was not the simplistic line drawing shown in Figure 2, but a photorealistic, nude male or female figure with full anatomical detail.

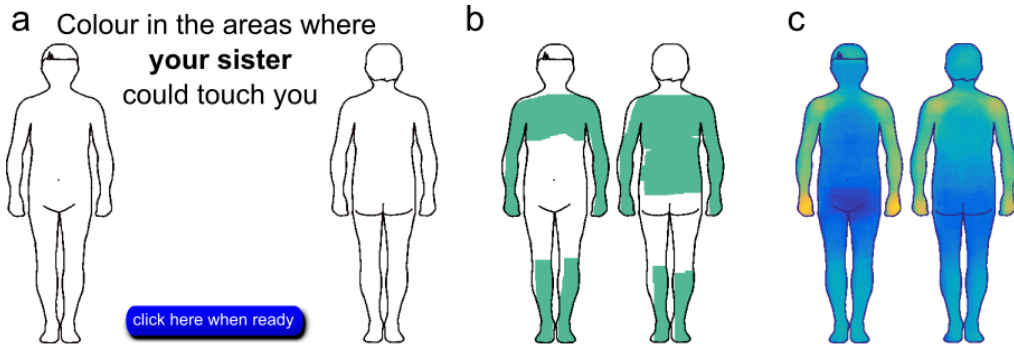


Figure 2. Data collection using the emBODY tool. (a) The screen shown to subjects with two empty bodies and colouring prompt. (b) Example of one subject's colouring response. (c) Example of resulting maps after data pre-processing and statistical analysis.

The data were stored as matrices, where both front and back of the body were represented by approximately 171 (width)*522 (height) pixels. After data collection, the data were screened for anomalous painting patterns, such as extensive painting outside of the body outline. The data from all subjects were then combined, and the results combined into statistical maps (Figure 2c).

3.4 Functional Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) can be used to study the structure and function of the brain. It is possible to build a high-resolution 3D model of an individual brain by measuring the different fat and water contents in different tissues in the brain (for a more complete explanation, see e.g. McRobbie, Moore, Graves, & Prince, 2006). While the structural imaging is of great relevance to clinical sciences, for the purposes of this thesis, we will focus on functional MRI.

Functional magnetic resonance imaging (fMRI) is based on the oxygenation-dependent magnetic properties of blood (Ogawa, Lee, Nayak, & Glynn, 1990). This can be used to detect changes in blood flow in the brain (Ogawa, Lee, & Kay, 1990). Using fMRI in human information processing is based on the observation that the blood oxygen level dependent (BOLD) response observed in somewhere in the brain reflects the local neuronal activity in that region (Logothetis, Pauls, Augath, Trinath, & Oeltermann, 2001). The BOLD signal arises from the increased metabolic demands of the regions with more neural activity (Logothetis et al., 2001). When an active brain area consumes oxygen, there is a temporary oxygen deficit. Then the vascular system compensates this by delivering a surplus of oxygenated blood to the site (P. T. Fox & Raichle, 1986), causing a large shift in the BOLD signal. The signal measured by fMRI is tied to this change in the ratio of oxygenated to deoxygenated blood at the site. Due to the dynamic by which the BOLD signal arises, there is typically a lag of around 6 seconds from the stimulus onset to peak signal (Buxton, Wong, & Frank, 1998).

fMRI is non-invasive and does not carry any health risks to healthy subjects if standard precautions are followed. fMRI allows monitoring of brain activity in the whole brain with a typical spatial resolution of 3-5mm³, and temporal resolution in the order of seconds. While other brain imaging methods can have better temporal or spatial

resolution, the combination of reasonable resolution in both time and space has made fMRI increasingly popular.

fMRI however has poor signal to noise ratio, and the non-task related vascular changes can further complicate data analysis. The relevant signal might be as little as 2% of the total BOLD response (Ashby, 2011). To overcome this issue, fMRI experiments typically require repeating a stimulus for a number of times. This, combined with complex data pre-processing enables extracting the signal from noise.

The scanning in Study IV was conducted using MAGNETOM Skyra 3.0 tesla scanner (Siemens, Erlangen) and a 32-channel receive head coil (Siemens). Whole-brain T2*-weighted EPI images were acquired with following imaging parameters: TR 1.52 s, TE 30 ms, flip angle 70°, 72 × 72 matrix, 2.7 × 2.7 mm² in-plane resolution, 35 slices (3.7 mm thickness, no gap), using water excitation. The experiment consisted of five EPI runs, totalling 2150 volumes of functional data. High-resolution anatomical images with isotropic 1 mm³ voxel size were collected using a T1-weighted MP-RAGE sequence. Respiration and cardiac rates of the subjects were measured during the EPI sequences using BIOPAC system MP150CE.

The most commonly used approach for analysing fMRI data is General Linear Model (GLM). It is the general form of different univariate methods used in analysing task-related fMRI data test (Friston et al., 1995). In a within-subject GLM, voxel-wise brain activation time series is fitted against a stimulation model (Friston et al., 1995). The voxel-by-voxel outputs are then collected to form statistical parametric maps (SPM), to reveal voxels showing task-related activation (Ashby, 2011).

While intuitively appealing and widely used, using GLM analysis of fMRI data has significant drawbacks. In GLM, the data are analysed voxel-by-voxel to reveal areas with a net activation change. This approach requires notably robust changes for voxels to survive the correction for multiple comparisons. GLM can also miss representations based on patterns of activity rather than net activation change (Davis & Poldrack, 2013).

A more recent view suggests that using a multivariate, rather than mass univariate, framework can help better understand cortical representations of sensory input or mental contents (Haynes, 2015). Indeed, several different types of stimuli can result in distinct patterns of activation in the same brain region (Haxby et al., 2001), leading to no detectable differences in SPMs. This has led to the rise of a different analytical approach, where the data are analysed for patterns of activation rather than individual voxels. One of the most popular methods to decode brain activation patterns is called multi-voxel pattern analysis (MVPA). MVPA is a machine learning method where a classifier is trained on a portion of the data (supervised learning), and then this classifier is tested on unseen portion of the data to assess generalizability.

This kind of multivariate approach increases the amount of information that can be decoded from the data. For example, it is possible to predict the direction of a pattern the subject is watching (Haynes & Rees, 2005), which semantic category a word the subject is attending to belongs (Mitchell et al., 2004), or which emotional state they are in (Saarimäki et al., 2018). This is relevant when working with stimuli, which are likely to be processed in the same cortical regions but can be assumed to be represented by distinct patterns of activity (Haynes, 2015).

4. Summaries of the studies

4.1 Topography of social touching depends on emotional bonds between humans.

4.1.1 Aims of the study

Non-human primates use social touch for establishing and maintaining social affiliations. Research in babies and caregivers suggests that humans might use touch in similar ways. If this is the case, it would be likely that the patterns in which social touch is used would differ between different social relationships. Indeed, previous research has suggested that there are relationship-specific patterns of acceptable social touch. In Study I, we aimed to quantify these patterns throughout the social network from partners all the way to strangers.

4.1.2 Methods

Study I comprises two experiments. The sample in Experiment 1 consisted of Finnish adults. For experiment 2, data was collected from Finland, France, Italy, Russia, and the United Kingdom. The tool was translated into the majority language of each sampled culture (Finnish, French, Italian, Russian, and English).

In Experiment 1, the participants were then shown a list of potential reasons for social touch (such as ‘greeting’ and ‘consoling’), and they were asked to report which members of their social network they would touch for that reason (yes/no). They were also asked to imagine they were at their home or at a public place with this person, and they then reported how likely (1=highly unlikely, 10=highly likely) they thought it was that they would touch this person while in this this location.

In Experiment 2, the participants indicated, using the emBODY tool, where in their body they would feel comfortable being touched by each social network member (explained in more detail in Section 3.3) The resulting topographies were screened for anomalous painting patterns and then combined to create Touch Area Maps (TAMs). The TAMs were calculated by mass univariate t-tests where the pixel intensity was compared against zero to reveal areas where touching is consistently acceptable. We then defined Touchability Index (TI) as the proportion of body area someone is allowed to touch (0 meaning that person is not allowed to touch any part of the body, 1 meaning they are allowed to touch everywhere), and correlated this with the ratings of emotional bond (1 = no emotional bond, 10 = strongest possible emotional bond). The members of the social network were also divided into theoretical layers: partner, family of origin, extended family, friends, acquaintances, and strangers. The Spearman correlations of

the topographies were compared with the hypothetical social network structure using Mantel's test.

4.1.3 Results

Experiment 1

Closer social network members were touched for more reasons. Most of the reasons for touch were relationship-specific ($\chi^2 \geq 34.72$, $P < 0.05$), with people more frequently reporting that they would touch closer individuals for these reasons than they would more distant individuals.

There were two exceptions to this. The frequency of ritualistic forms of touch (touch when greeting and parting) occurred similarly in all relationships (Figure 3). Negative reasons for touch (punishing, hurting, scaring) were markedly absent and also did not differ significantly between the relationships

In general, participants reported that they would be significantly more likely to touch different members of their social network when at their own home than when at a public space or at their place of work or study (Figure 4). A two-way ANOVA (2 levels of sex of target individual * 3 levels of context) on the likelihood of touching revealed significant main effect of context $F(2,1887) = 29.7$, $p < 0.001$ and a significant main effect of the sex of the target individual $F(1,1887) = 11.5$, $p < 0.001$. The interaction was not significant, $F(2,1887) = 0.078$, $p = 0.92$.

Post-hoc two sample t-tests revealed that touching was significantly more likely at home ($M = 5.63$, $SD = 3.3$) than in public ($M=4.56$, $SD= 3.2$), $t(1259.2) = 5.79$, $p < 0.001$, or than in the workplace ($M = 4.33$, $SD = 3.057$), $t(1252.4)=7.25$, $p < 0.001$. There was no significant difference in likelihood of touch in public and at work $t(1265.5)=1.34$, $p = 0.18$. Touching is also more likely when the person being touched is a woman ($M=5.10$, $SD = 3.2$) than man ($M=4.60$, $SD =3.3$), $t(748.85) = 13.57$, $p < 0.001$.

Experiment 2

We found clear relationship-specific topographies of acceptable social touch (Figure 5). The partners were allowed to touch largest areas of the body, and male strangers the smallest. We also discovered some taboo-zones, i.e. areas where touch was consistently considered not acceptable. These were mainly located around crotch and bottom for male family and extended family members and male acquaintances, extending through torso and upper legs for male strangers. In general, for all male and female pairs with the same formal relationship with the subject (e.g. sister and brother), the females were allowed to touch larger bodily areas than the males ($P_s < 0.05$, two tailed two-sample t-test) (Figure 6). The topographies were highly consistent with the hypothetical social network structure (Figure 7), Mantel correlation statistic $r = 0.45$, $p \approx 10^{-7}$. The topographies were also consistent across the five cultures, with Spearman $r_s > 0.79$, $p_s \sim 10^{-45}$.

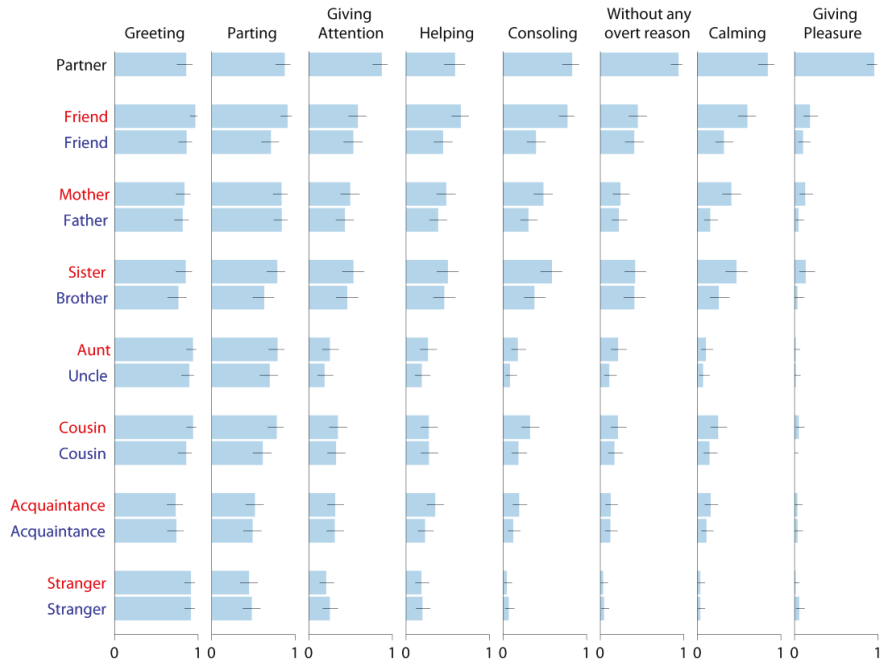


Figure 3. The proportion of respondents who reported that they would touch this member of their social network for this reason. Error bars depict 95% confidence intervals. The red and blue labels indicate female and male members of the social network, respectively. Figure from (Suvilehto, Glerean, Dunbar, Hari, & Nummenmaa, 2015)

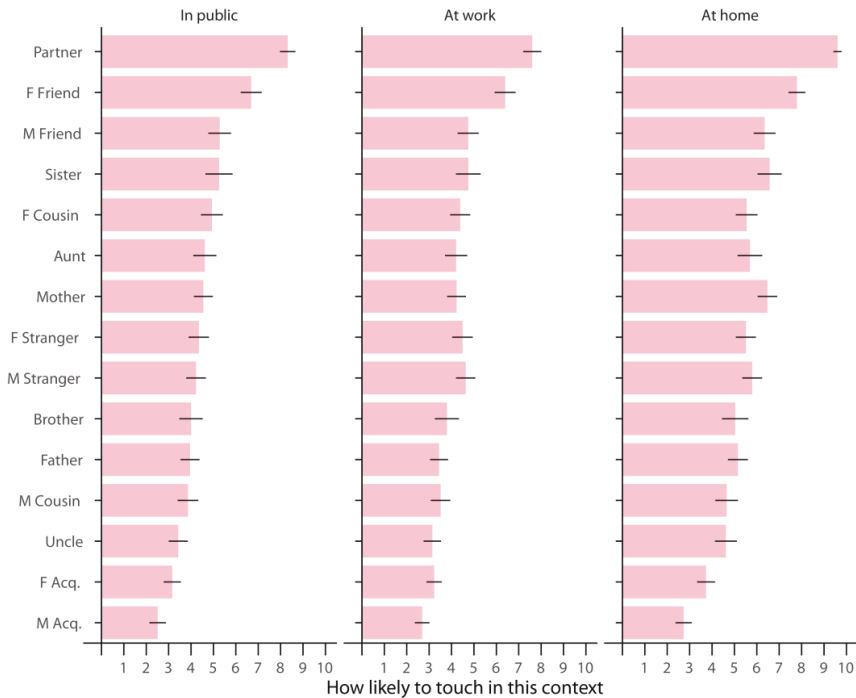


Figure 4. Social touch in different contexts. Averages of how likely participants thought that they would touch different members of their social network at their own home, at their own place of work / study or at a public place such as the street. The scale was discrete, ranging from 1 (not at all likely) to 10 (extremely likely). The bars represent the average responses and error bars depict SE

There was a linear relationship between the emotional bond between the subject and the toucher, and the total body area allowed for touch in all of the five cultures mean ($r^2 = 0.64$; Figure 8). As the bottom right panel in Figure 8 shows, regression coefficients were concordant across the countries ($P > 0.05$ for differences between β values). There is, however, a difference between the constant term in the regression lines, i.e. the baseline acceptability (how much a person, with whom you feel no emotional bond, is allowed to touch you). The baseline acceptability was highest in Finland, followed by France, Russia, Italy, and the United Kingdom.

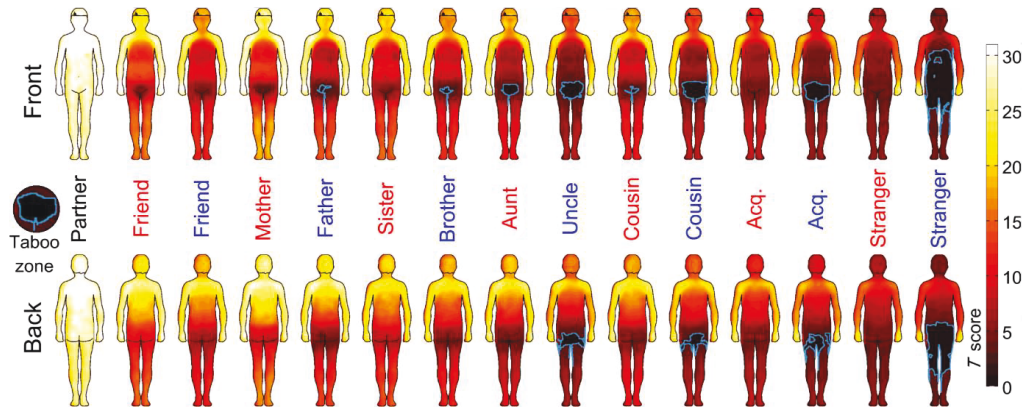


Figure 5. Relationship-specific TAMs for each of the social network members from the complete data set ($N=1368$). The data are thresholded at $P < 0.05$, FDR-corrected. Colour bar indicates the t statistic range. Blue and red labels signify male and female social network members, respectively. The areas outlined in blue are taboo-zones, where touch by that social network member was not appropriate.

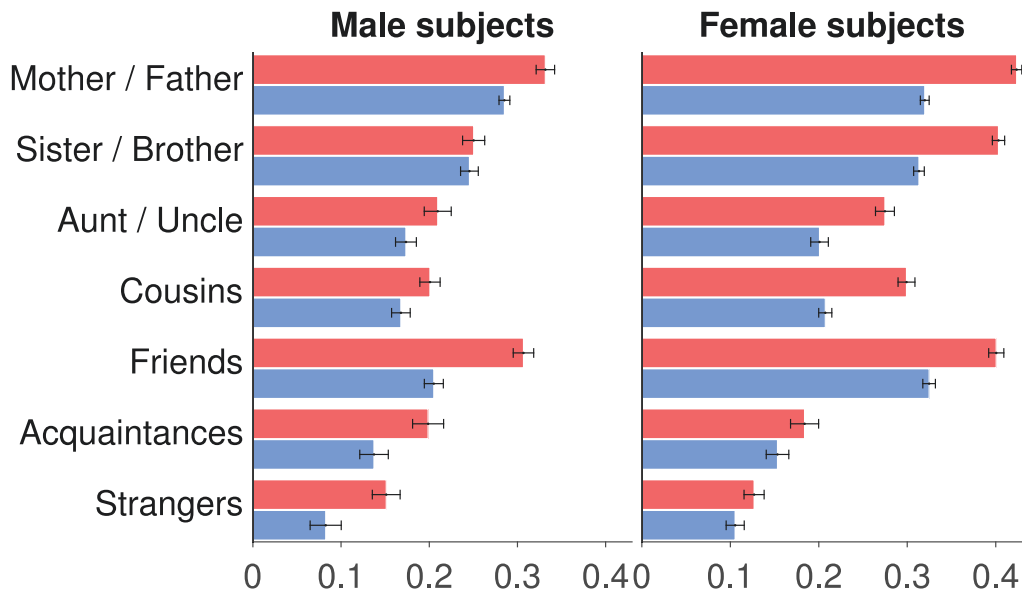


Figure 6. Sex differences in TIs reported by male (left) and female (right) subjects. Error bars indicate standard error of mean. Red and blue bars signal female and male touchers, respectively.

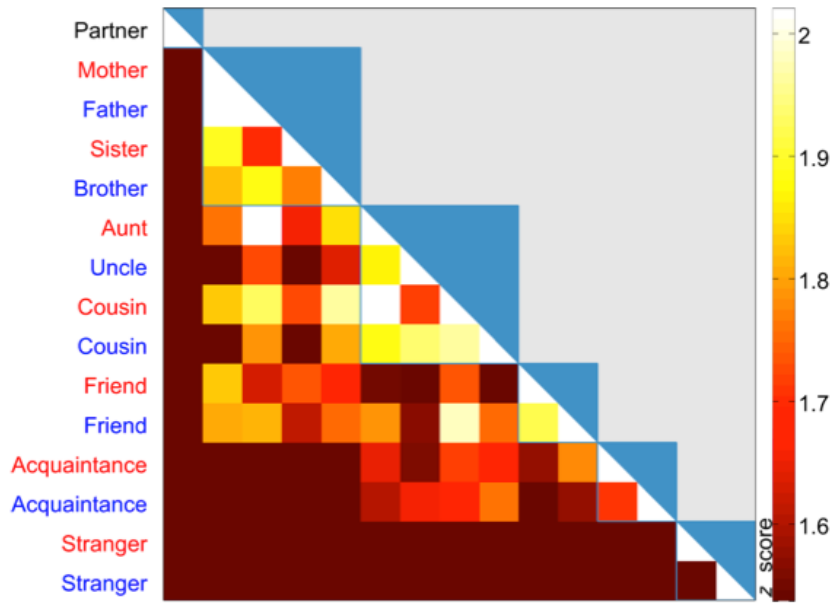


Figure 7. TAM-based similarity between the different members of the social network. The adjacency matrix is symmetric, and the same order of labels holds for the horizontal axis. Lower triangular matrix shows the z-transformed Spearman correlation between the average spatial maps. Upper triangular matrix demonstrates the a priori social network layers (from left to right: family, family of origin, extended family, friends, acquaintances, and strangers). Within each ideal network block, the block (light blue) is assumed to be fully correlated and have zero correlation elsewhere (light grey areas). For visualisation purposes, the figure only shows values exceeding the median across all map pairs. Blue and red labels signify males and females respectively.

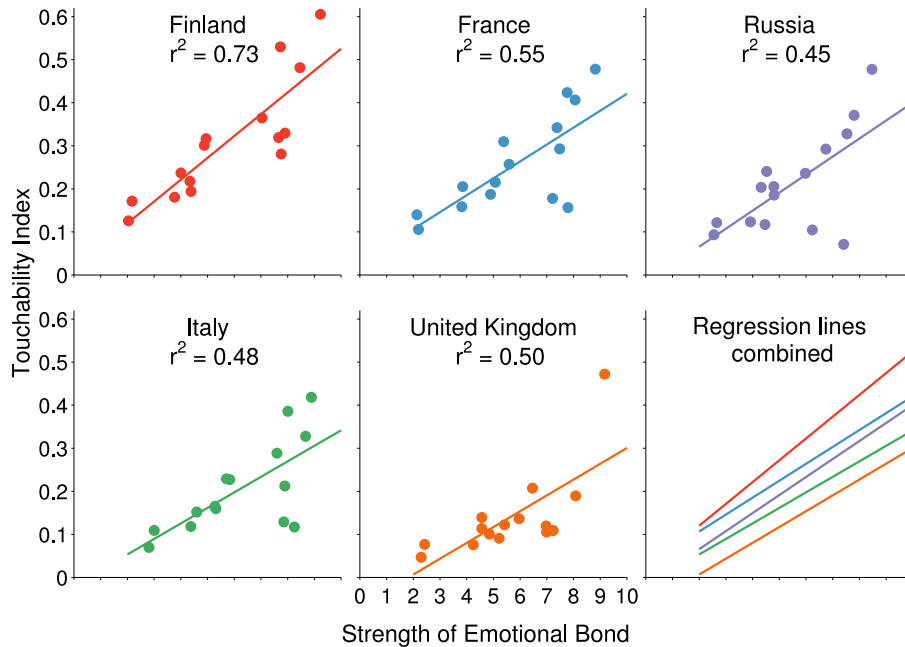


Figure 8. Association between the TI (y axis) and emotional bond (x axis) in each of the studied cultures. Each dot represents the average TI and emotional bond for one member of the social network from one country. The last panel shows linear regression lines from the five countries together to facilitate comparison.

The touchability of most body areas apart from the hands was strongly correlated with the emotional bond between the subject and the toucher, and the position of the toucher in the subject's social network. Conversely, the time since last seeing a person was only minimally (albeit statistically significantly) negatively correlated with the touchability of different areas (Figure 9).

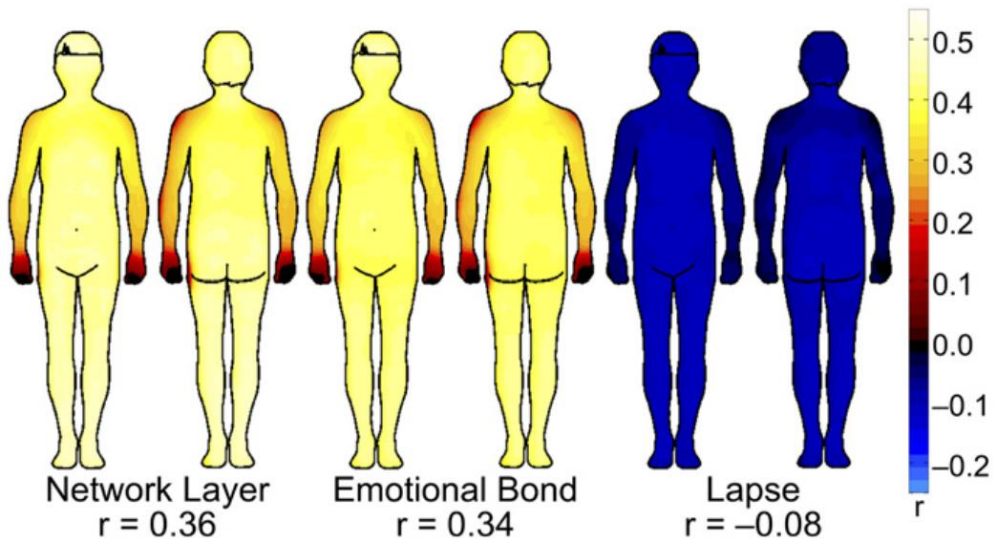


Figure 9. The pixel-wise correlations between touchability and social network layer (left), emotional bond (middle) and time since last meeting a person (right). The data are thresholded at $p < 0.05$, FDR corrected. Color bar indicates the r statistic range. Figure from (Suvilehto et al., 2015).

4.1.4 Conclusions

People in closer relationships were touched for more reasons and they were more likely to be touched in different contexts. Apart from ritualistic touch, most reasons for touch were sensitive to the social relationship. Likelihood of touching was context-specific such that people reported that they would be more likely to touch other people at their own home than a public space or at work. However, the variation between contexts was much less than the variation between different relationships. These findings highlight the relevance of inspecting touch from a relationship-specific perspective. Our results also showed that topographies of acceptable social touch were relationship-specific. These topographies were remarkably consistent between the five different cultures and reflected the composition of the social network. Moreover, the area allowed for touch was linearly and positively associated with the emotional bond with the toucher and this relationship was similar in all five cultures. These results suggest that the strength of the emotional bond modulates both the touchability of individual areas within a body as well as the TI. Taken together these results suggest that the topographical acceptability of social touch is dependent on the strength of the emotional bond. It is possible that this reflects a mechanism for establishing and maintenance of social bonds in humans.

4.2 Relationship-specific social touching is culturally universal

4.2.1 Aims of the study

The Experiment 2 of Study I showed surprisingly little cultural variation, which might be partially due to the fact that the included cultures were all mainly Western European. Studies have shown that Western and Eastern cultures differ with respect to, for example, communication style (Kowner, 2002) and experiencing emotions (Kitayama, Mesquita, & Karasawa, 2006). To test whether the relationship-specific use of social touch is exclusively a Western phenomenon, we repeated Experiment 2 from Study 1 in Japan, an Eastern Asian country. By comparing the British sample from the previous Study and the new Japanese sample, we extended our work on the cultural universalism in social touch to culturally more distant countries.

4.2.2 Materials and methods

Experimental protocol was similar to that in Experiment 2 of Study I. Because the emphasis of the current Study was on cultural comparison, we also included questions of the subjects' cultural heritage: The participants in the Japanese sample were asked to provide information about their parents' ethnicity and whether they had ever lived outside Japan. The participants in the English sample also answered background questions on their nationality and cultural identity.

To ensure that we were truly comparing the Japanese and British touching behaviour, we limited the sample to unambiguously Japanese and British respondents. The background questions were used to eliminate responses, where there was a clear risk of cultural ambiguity. Elimination criteria in the British sample included reporting something other than English as first language, or not mentioning 'British', 'Irish', 'Welsh', 'English', or 'Scottish' in the cultural identity. Altogether 159 British subjects were eliminated. For the Japanese sample, the elimination criteria included reporting either parent as being something other than 'Japanese' or having lived more than one year abroad. 17 Japanese subjects were eliminated in the background screening.

Due to the differences in the sample sizes, the TAMs were calculated as proportion of subjects reporting each pixel as acceptable. The difference between Japanese and British TAMs was determined by two sample z-test of proportions.

4.2.3 Results

Topographies of touch allowances were concordant in the Japanese and British samples. The main differences were higher touchability of the partner in Britain and higher touchability of legs and bottom by female relatives in Japan (Figure 10). There were also a few topographical differences in the more distant social relationships. Namely, the British reported higher touchability in hands of male stranger and cheeks in mother, aunt, female cousin and female friend.

Both emotional bond and pleasantness of touch were correlated with the TI (Figure 11). These associations were similar in both countries, but the Japanese overall found touch less pleasant than the British. Due to the high correlation between emotional bond and pleasantness of touch, partial correlation tests were also run. These revealed

that, when controlling for the pleasantness, the association between emotional bond and TI remained significant, $r = 0.15$, $p < 0.0001$. Similarly, when controlling for emotional bond, the association between pleasantness and TI was also significant, $r = 0.22$, $p < 0.0001$. Thus, both pleasantness and emotional bond contribute independently to the relationship-specific TI.

We also conducted topographical region of interest (ROI) based analyses for the association between emotional bond and ROI-wise TI (Figure 12). Most regions had similar linear regression lines in both cultures, with only hair, arm, and hand showing different slopes for the two cultures. In all of these ROI the slope was steeper in the Japanese sample, suggesting that an equal increase in emotional bond results in a larger ROI-wise TI increase in the Japanese culture.

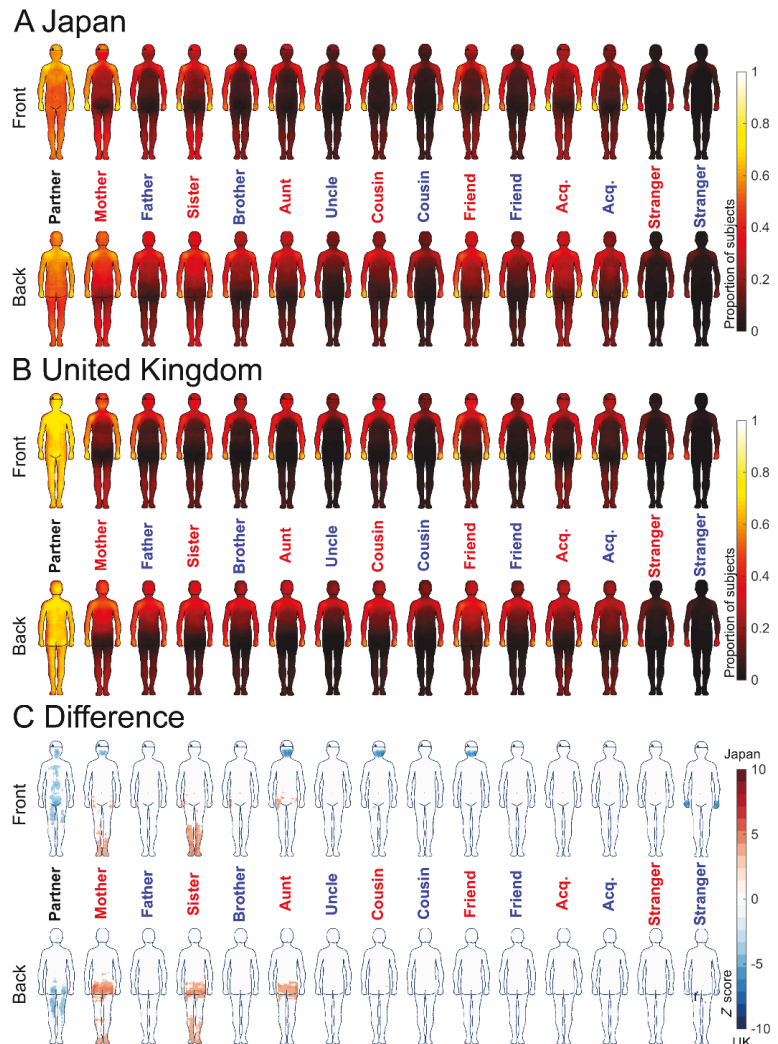


Figure 10. The touch area maps (TAMs) in Japanese (A, top row) and British (B, middle row) participants. Colourbar shows the proportion of subjects accepting touch at each location for each social network member. C) Statistically significant differences in the TAMs between the two countries as determined by pixel-wise two sample z test of proportions. Warm colours indicate areas which are more touchable in Japanese sample, blue colours indicate areas which are more touchable in the British sample. The blue and red labels indicate male and female members of the social network, respectively.

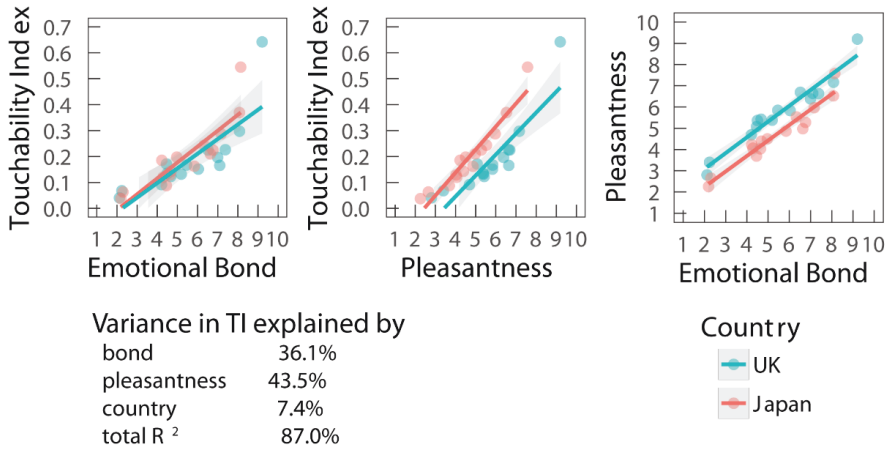


Figure 11. Touchability Index (proportion of body area allowed to touch, TI) as a function of the emotional bond (top left) and how pleasant the touch is (top right). Each dot represents the average for a member of the social network in one country (e.g. ‘Japanese mother’). The pleasantness and bond are strongly correlated with one another (bottom left), but both also independently explain some of the variation of the TI as evidenced by the partial R²s (bottom right), calculated by averaging over orders.

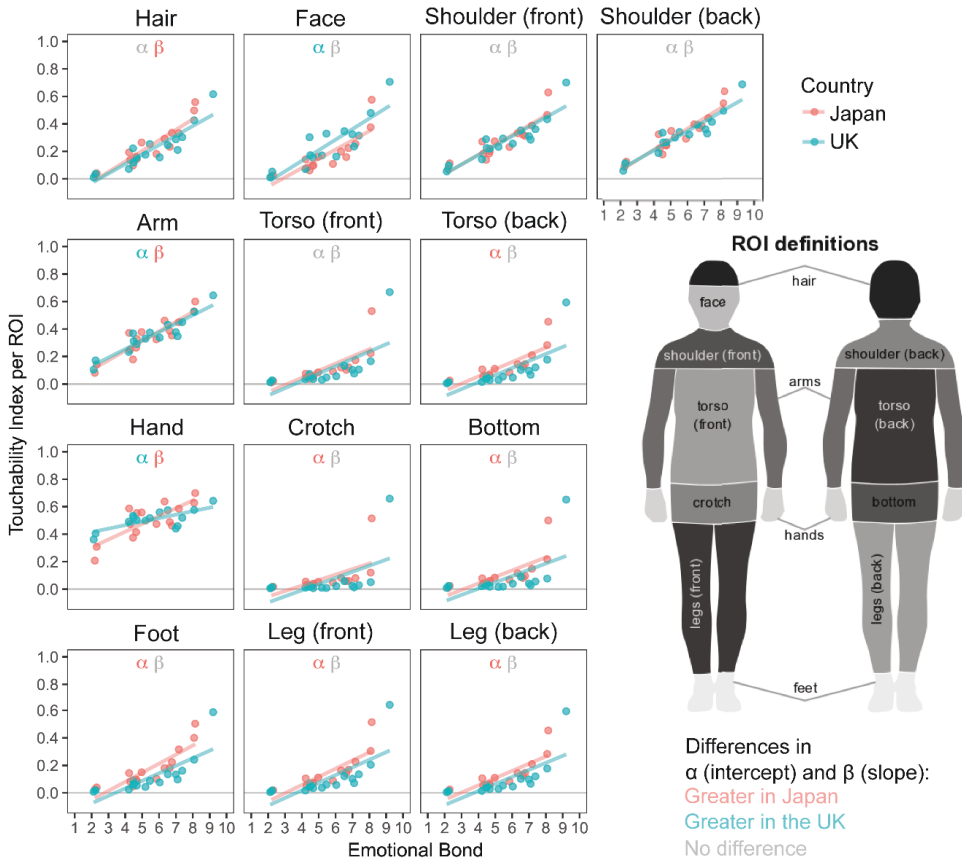


Figure 12. ROI-wise analysis of the relationship between emotional bond and ROI-wise TI. The visualisation shows averaged data, with each dot representing the average responses to one member of the social network in one culture. The comparisons between the intercept and slope are done with the un-averaged data.

4.2.4 Conclusions

The acceptability of social touch was highly consistent in the two cultures. There were very few differences in pixel-wise, ROI-wise or whole-body TI comparisons: the variance in TI explained by the culture was less than 8%. Moreover, most of the observed differences are likely to be related to culturally normative ritualistic touch. For example, touching was more acceptable in Britain on hands for male strangers, cheeks for female friend, female cousin, aunt, and mother, all of which can be explained by greeting behaviour. Apart from differences in ritualistic touches, the differences in the topographies of acceptable touch were focused on female relatives and the partner. The average emotional bond with partner was also less than the average emotional bond in the UK, so these findings might indicate larger differences in the intimate relationships in Japan and the UK. Finally, we also found that while pleasantness and emotional bond are highly correlated, they both independently explain some of the TI. The causality in this interaction is not yet clear and requires further research.

4.3 Topography of Human Erogenous Zones

4.3.1 Aims of the study

Touching is one of the most powerful means for triggering positive affect. In reproductive pair bonds touching can also be used in eliciting sexual arousal. This is in contrast with affiliative relationship, where sexual aspects of touch are lacking. Many different areas of the body have capability for triggering arousal response via human touch (Turnbull et al., 2014). This kind of touching can trigger and maintain sexual arousal and thus prepare the individual for copulation. In this study, we investigated the potency of different body areas for eliciting sexual arousal when touched, and in particular, how the use of touch differs when masturbating or having sex with a partner. If the main purpose of touch during sex is obtaining sexual release, we should observe similar topographies for both situations. If the topographies of erogenous zones are different in the two conditions, this would suggest that touching serves additional functions.

4.3.2 Materials and methods

The participants provided demographic information and estimated their own attractiveness. Using the emBODY tool, they then indicated the bodily regions capable of triggering sexual arousal. On separate trials, subjects indicated those bodily areas whose touching they find sexually arousing while 1) masturbating or 2) while having sex with a partner. To enable evaluation of subjects' knowledge of the erogenous zones of members of the opposite sex, the subjects were also asked to estimate which bodily areas a member of the opposite sex would find sexually arousing during 3) masturbation or 4) having sex with a partner. These results were collected using the emBODY tool and analysed pixel-by-pixel to give statistical erogenous zone maps (EZMs). The extent of erogenous zones in masturbation and sex with partner was calculated as a proportion of the complete body area. The responses of both sexes were compared by contrasting self-reports from each sex with estimates from the opposite sex.

4.3.3 Results

We found that significantly larger bodily area is considered erogenous when having sex with partner than when masturbating (Figure 13). The self-reports indicated that, on average, 26% of the female and 22% of the male body was considered erogenous when having sex with a partner. For masturbation, only 6.3% and 4.3% of the bodies were considered erogenous by females and males, respectively.

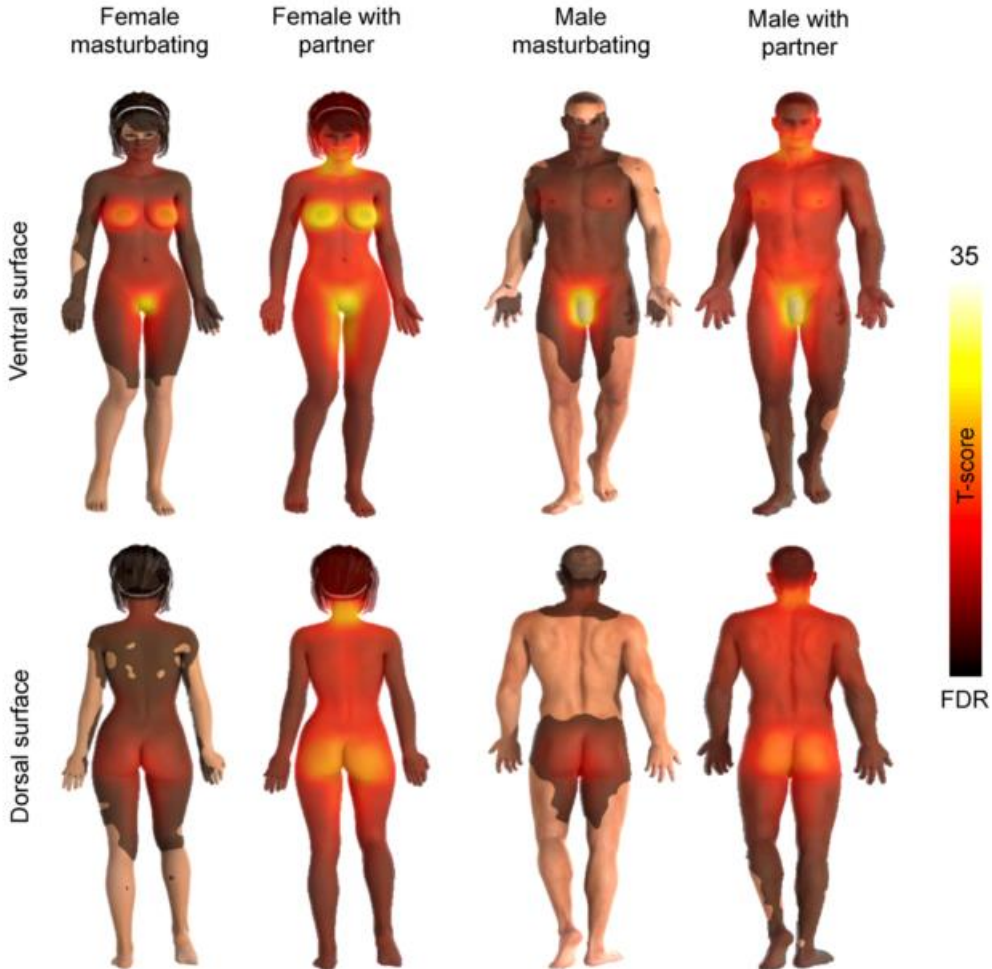


Figure 13. Maps of the erogenous zones of women and men when masturbating or having sex with a partner. The data are thresholded at $p < 0.05$, false detection rate corrected. The colour bar indicates the t-statistic range in one-sample test.

The erogenous zones were of equal sizes in men and women when having sex with partner ($t(268.11) = 1.66$, $p\text{-value} = 0.098$), but were larger for women ($M = 0.062$, $SD = 0.094$) than men ($M = 0.045$, $SD = 0.053$) when masturbating ($t(540.54) = 3.08$, $p\text{-value} = 0.002$) (Figure 14). Moreover, the assumed erogenous zones for opposite sex were highly correlated with the responses from subjects of that sex. This was especially true for sex with partner, with average Pearson correlation for the topographies of sex with partner at 0.93 ($p < 0.01$) (Table 3).

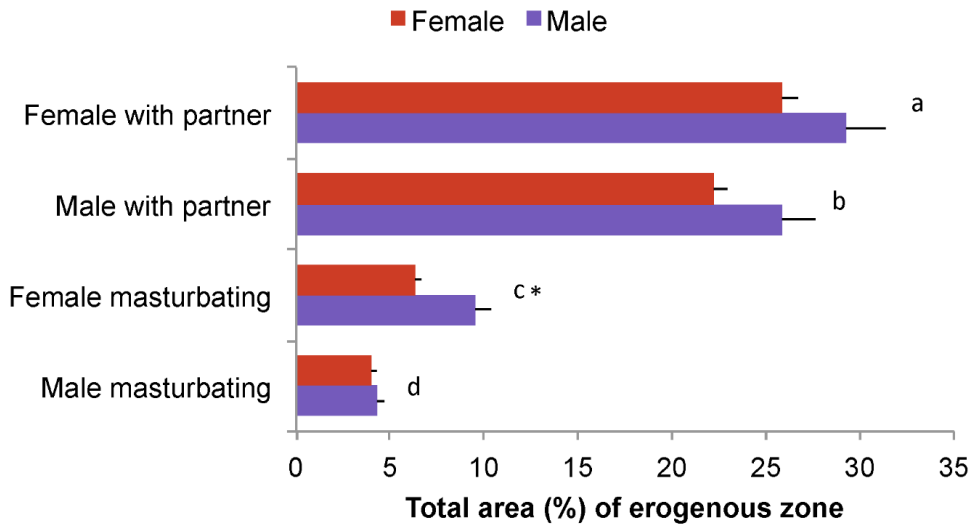


Figure 14. Effects of participant sex and type of sexual activity on the size of erogenous zones (defined as % of the whole body). Error bars show standard error of the mean.

Table 3. Pearson correlations between averaged, condition-wise erogenous zone maps reported by male and female participants and the estimations presented by the opposite sex. All shown correlations are significant at $p < 0.05$

Condition	<i>r</i>
Female ventral with partner	0.95
Female dorsal with partner	0.95
Male ventral with partner	0.92
Male dorsal with partner	0.91
Female ventral masturbation	0.85
Male ventral masturbation	0.78
Female dorsal masturbation	0.59
Male dorsal masturbation	0.35

4.3.4 Conclusions

These results suggest that the whole human body is capable of triggering sexual arousal by somatosensory stimulation. On average, participants reported around 5.6% of the body surface as erogenous while masturbating, while they reported around 23% of their body as capable of triggering sexual arousal when having sex with a partner. The difference between the core erogenous zones in masturbation and extended erogenous zones in having sex with a partner is quite sizeable, approximately 17.4%. This begs the question: If the most efficient way to obtain sexual release is to focus on core erogenous zones, why are the extended erogenous zones touched during sex with partner? Expending energy in this way suggests that touching during sex with partner might also serve other functions in addition to sexual arousal. One potential explanation is that touch is used for reinforcing the pair bond during sex.

4.4 Relationship-specific encoding of social touch in somatosensory and insular cortices

4.4.1 Aims of the study

Previous research has shown that social touch is perceived differently depending on who the toucher is. In particular, touch by a stranger and touch by a partner are experienced differently with respect to pleasantness and acceptability. In this Study, we investigate the brain basis of extracting relationship-specific social information from touch. Unlike previous work, we included the subjects' actual romantic partners, we studied both men and women, and we had both man and woman strangers to contrast with.

4.4.2 Materials and methods

Ten heterosexual romantic couples participated in the experiment. One subject interrupted scanning, citing discomfort, leaving 19 subjects with sufficient imaging data. The subjects were acquainted with the experimental set-up and task before commencing with scanning. Both partners were always scanned, with the male-female order counter-balanced across the couples. The experimental design is shown in Figure 15. Three confederates (the subject's romantic partner, a female research assistant and a male research assistant) took turns in bringing their hand to the subject's visual field at moderate distance or near their thigh or touching the subject's upper thigh. The confederates were trained to stroke the thigh in uniform CT-optimal speed (approx. 4cm/s) and they were given heat pads to ensure consistent hand temperature. The confederates wore different coloured overalls, and the subject was told prior to scanning that they could recognise their partner and the two strangers by the sleeves. The subject was told to pay attention to the hand during the stimulus, but no further task was given. In each EPI run, 9 stimuli were designed as 'catch' trials, where the same assistant immediately continued from one stimulus to another (with the latter stimulus being closer to the subject than the first one) without inter stimulus interval.

The data were pre-processed using the FSL tool and custom Matlab code. In short, MCFLIRT was used to correct the EPI series for slice timing differences and for head movement. Cardiac and respiratory related signal were cleaned out using the DRIFTER toolbox (Särkkä et al., 2012). FLIRT was used to register images to the MNI152 2mm template. Scanner drift was removed using a Savitzky-Golay filter (window length 240 seconds) and high-pass temporal filter with a 0.01 Hz cut-off frequency. Finally, the BOLD time series were cleaned using 24 motion-related regressors, signal from deep white matter, ventricles, and cerebrospinal fluid to control for physiological and motion artefacts. Pre-processed data were also inspected for extensive motion.

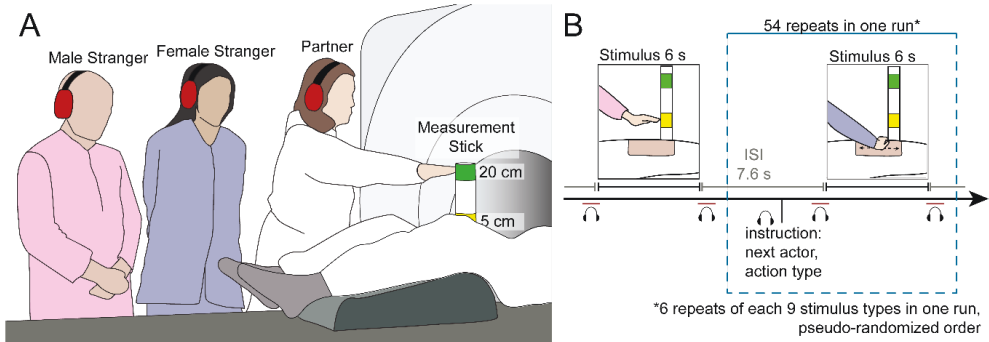


Figure 15. (A) Experimental set-up in the scanner room. All three confederates stood by the scanner bore, out of the view of the participant, and took turns in either bringing their hand to the visual field of the participant or touching the participant's upper thigh. (B) Timing of the stimulation. The stimulus type and actor as well as the onset and offset of the stimulation were communicated to the confederates via headphones.

4.4.3 Results

Whole-brain GLM analysis showed that being touched increased activation in insular cortices (INS), secondary somatosensory cortices (S2) and the contralateral primary somatosensory cortex (S1) (Figure 16). Significant differences were seen in S1, S2, and anterior cingulate cortex (ACC), when seeing hand and experiencing touch were contrasted against one another. GLM did not however reveal any statistically significant differences across actor identities.

Next, MVPA was used to detect relationship-specific patterns of activation for seeing and anticipating touch. A MVPA classifier using a linear support vector machine kernel was run in a number of regions of interest (ROI). The bilateral regions of interest were defined in areas related to somatosensation or emotion and reward processing. Additional ROIs were set for visual cortex (VC) and the whole brain minus visual cortex. When classifying between the three different actors (partner, female stranger, male stranger), both whole brain minus visual cortices and S1 were able to classify all three conditions at above chance level (Figure 17). Furthermore, it was possible to classify the actor in touch also from the insular cortex and actor in anticipating touch (seeing hand at 20cm) from the visual cortices.

Finally, we focused on touch and ran binary classifiers between two actors at a time. The classification between partner and opposite-sex stranger (i.e. stranger and partner were of the same sex) was successful in several ROI (Figure 18). Whole brain minus visual cortices, S1, S2, amygdala and orbitofrontal cortex were all able to classify between these two touchers at above chance level. Moreover, primary somatosensory cortex was able to differentiate between partner and female stranger and insular cortex was able to differentiate between partner and male stranger.

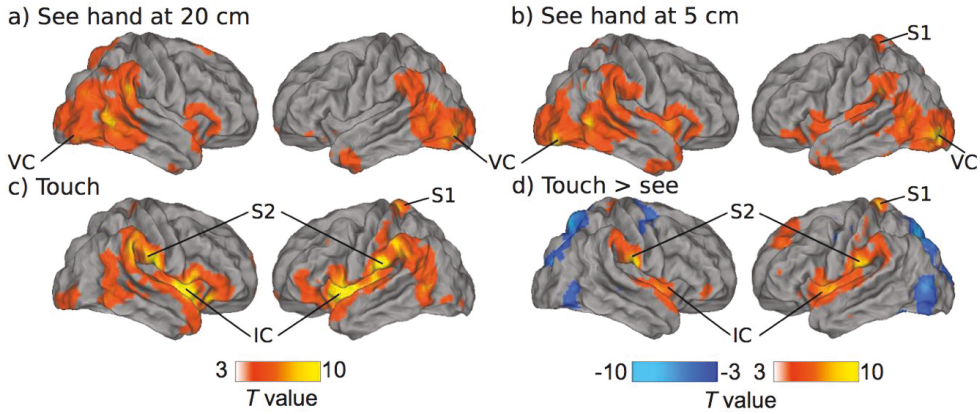


Figure 16. GLM analysis shows increased activity (main effects) in seeing the hand at 20cm (a), 5cm (b) and being touched (c). The contrast being touched - seeing hand (d) revealed significant differences in primary and secondary somatosensory cortices and anterior cingulate cortex. Data are thresholded at $p < 0.05$, false discovery rate corrected.

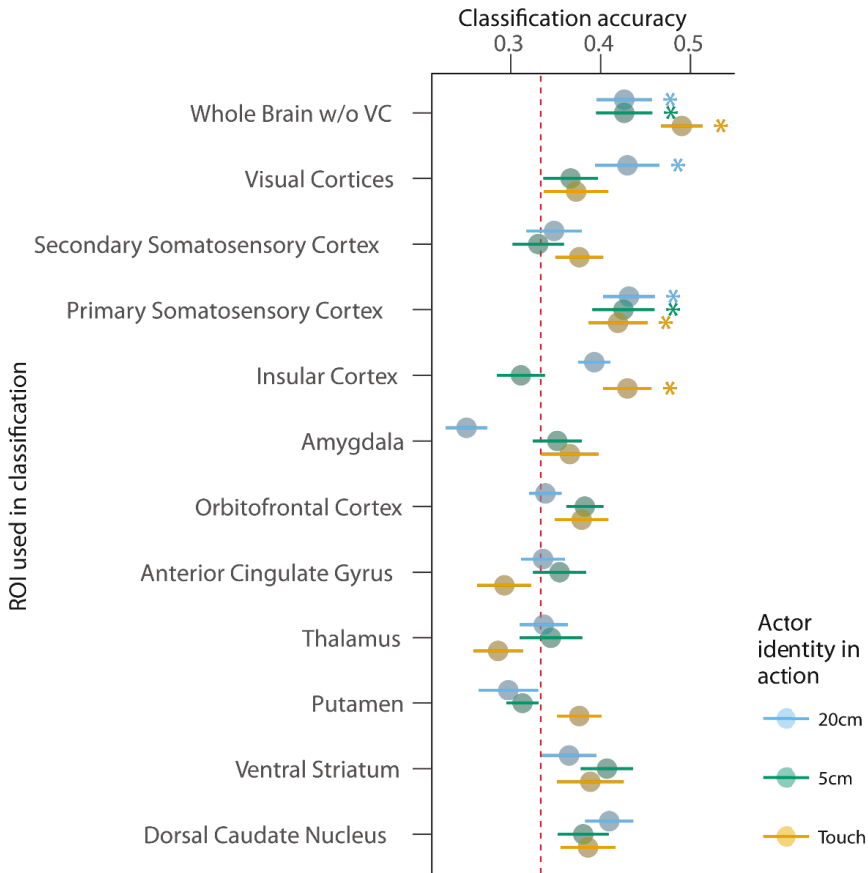


Figure 17. The classification accuracy of the actor identity (partner, female stranger, male stranger) in seeing the hand at 20cm, seeing the hand at 5cm, and touch. The whole brain minus visual cortices and the primary somatosensory cortex were able to classify actors above chance level in all three event types. Visual cortices were able to classify actor in seeing hand at 20cm, and insular cortices were able to classify actor in touch. Dashed line indicates a-priori chance level (0.33), error bars show SEM, * denotes $p < 0.05$ (FDR corrected).

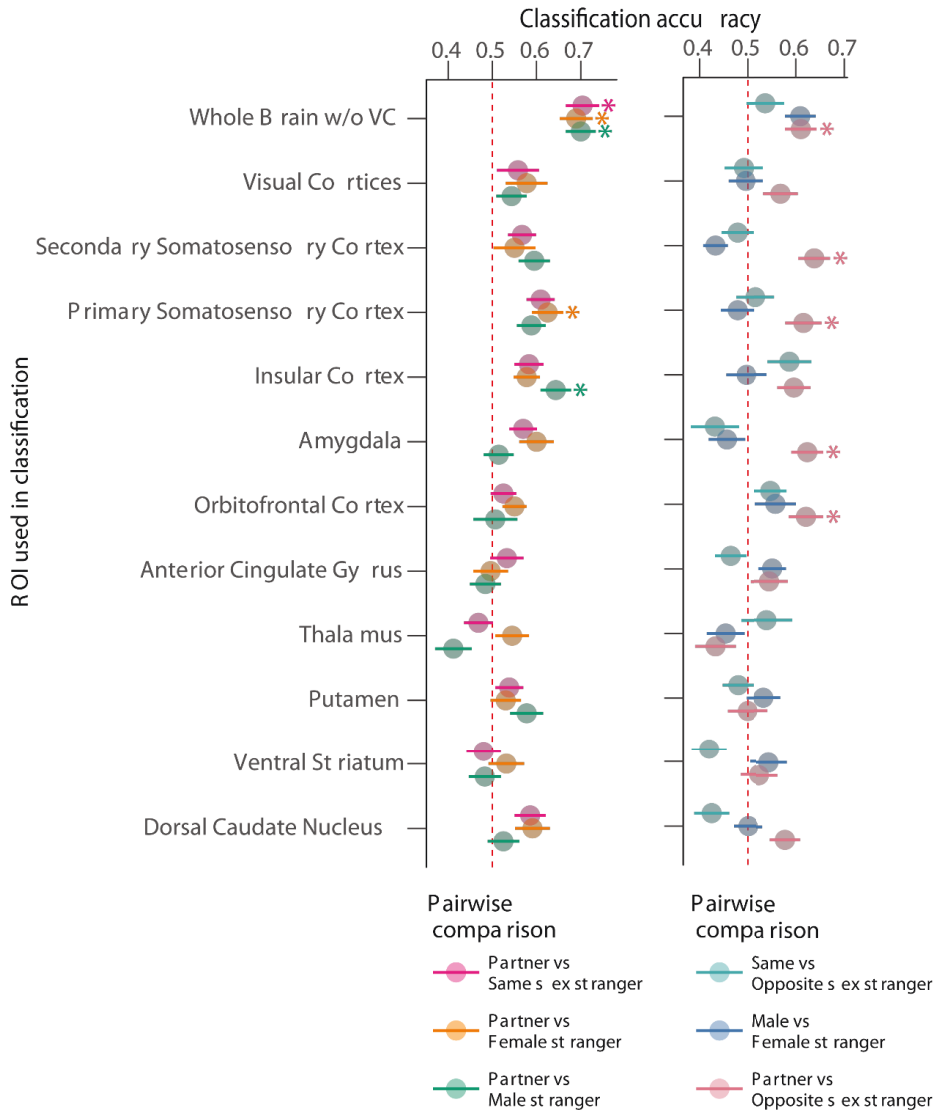


Figure 18. Binary classifications of actor identity in touch. (Left) Whole brain without visual cortices was able to classify partner vs male stranger, partner vs female stranger and partner vs same sex stranger. Primary somatosensory cortex was able to classify partner vs female stranger, and insular cortex was able to classify partner vs male stranger above chance level. (Right) Partner and opposite sex stranger were classified most reliably, and the classification accuracy was above chance level in whole brain minus visual cortices, primary and secondary somatosensory cortices, amygdala, and orbitofrontal cortex. Dashed line indicates a-priori chance level (0.5), error bars show SEM, * denotes $p < 0.05$ (FDR corrected).

4.4.4 Conclusions

Our findings indicate that several brain regions are involved in the processing of social touch. While GLM was not sensitive to visual, somatosensory and affective differences between the three actors, MVPA analysis revealed several brain regions capable of differentiating between the actors. This suggests activation patterns relate to social relationship with the toucher as opposed to global signal change. Three-way classification for touch was only possible in S1 and insular cortex (and naturally the whole brain

minus visual cortices, which includes both S1 and insular cortex). Binary classifications of actors revealed that partner versus opposite sex stranger (i.e. male partner versus male stranger and female partner vs. female stranger) could be classified most accurately and in most ROIs. Additionally, insular cortex classified partner vs male stranger and S1 classified partner vs female stranger at above chance level. Classification of the two strangers was not successful regardless of how they were defined. These results confirm the role of primary somatosensory cortex in representing relationship-specific features of social touch and touch anticipation (Gazzola et al., 2012). They also suggest that insular cortices contain a complex representation of relationship-specific touch, but not touch anticipation. Because binary classification was most successful when classifying based on social relationship (partner or stranger) while keeping the sex of the toucher constant, the results suggest that these areas contain a more limited representation of toucher identity.

5. General discussion

The main finding of this Thesis was that social relationship between two individuals modulates numerous features of social touch: how pleasant the touch is (Studies I-II, IV), how large an area of the body is allowed for touching (Studies I & II), why and in which contexts touch is likely to occur (Study I), and even how the touch is represented on a cortical level (Study IV).

5.1 Patterns of social touch

Study I experiment 1 confirms that touching is more common at home than in public settings. This is in line with results suggesting that more touches occur at home than in public or work spaces (Willis & Rinck, 1983). It is possible that the touching at home differs functionally from touching at public spaces (Willis & Rinck, 1983). The differences in quantity and quality of touches in public spaces and other places highlights the need to study social touch using methods such as self-reports.

There was a continuum in the extent of the acceptable touch areas from partners, who were allowed to touch the whole body, to strangers, whose touching was limited to hands and arms. Moreover, the topographies tended to be more similar within each layer of social network than between different layers (Figure 7). There is one notable exception: male members of closer social network layers tended to have TAMs more similar to the female members of the next layer (e.g. father vs aunt, brother or male friend vs female cousin).

In general, male members of a social network were allowed to touch less than female members with the same formal relationship (e.g. sister and brother; male and female friend, see Figure 6). This is somewhat surprising, given that prior research has mainly focused on and described the differences in same sex and opposite sex touch (Heslin & Alper, 1983; Jones, 1986; Jourard, 1966; Major et al., 1990; Nguyen et al., 1975). For example, earlier studies have found that both men and women engage in more cross-sex touch (Major et al., 1990) and find cross-sex touch both more acceptable (Jourard, 1966) and more pleasant (Heslin & Alper, 1983) than same sex touch.

There is a discrepancy between our findings showing that female touch is more acceptable, and earlier results suggesting that opposite-sex touch is more acceptable (Barnlund, 1975; Heslin & Alper, 1983; Heslin et al., 1983; Jourard, 1966; Rosenfeld et al., 1976). This inconsistency might be explained by the fact that several of these old studies compare touch between “close same sex friend” and “close opposite sex friend”, with the latter being used as an euphemism for romantic partner (a use made explicit

in (Nguyen et al., 1975)). This suggests that the apparent discrepancy is a consequence of comparing romantic relationships with affiliative friendship. When comparing the current results with earlier work on other social relationships, for example, parents (Jourard, 1966), similar effect of mothers' touch being more acceptable than fathers' touch is found.

5.1.1 Touch within a romantic partnership

Touching between partners seems qualitatively and quantitatively different than touching in other, kin-based or affiliative relationships. We found that partners are touched for the most reasons, and they are allowed to touch the most areas. Partners are also very likely to be touched in different contexts. The extensive touching between partners has many benefits. More frequent touching with romantic partners is associated with higher relationship satisfaction (Gulledge et al., 2003; Heiman et al., 2011; Kontula, 2016; Muise et al., 2014). Moreover, touching intervention can improve relationship satisfaction (Floyd et al., 2009), suggesting that the relationship between touching and relationship satisfaction is not merely correlational but indeed causal.

Touching is also used for eliciting sexual arousal and for sexual stimulation. Having sex with a partner optimally involves widespread stimulation of most of the body ('extended erogenous zones'), which is arguably not necessary for sexual arousal and climax (Nummenmaa, Suvilehto, Glerean, Santtila, & Hietanen, 2016). Cuddling, which also involves touch on extensive body areas but is considered non-sexual, has been found to boost the feelings of closeness and affection (Van Anders et al., 2013). The lesser arousal potential in extended erogenous zones and the relationship-boosting effect of cuddling suggest that the purpose of the stimulation of the extended erogenous zones while having sex with a partner is not solely sexual arousal and release, but it might also serve as a tool for servicing the relationship.

5.1.2 The role of pleasantness in social touch

Pleasantness of touch is an important feature of social touch. The pleasantness of a touch depends on the type of touch, with slow, stroking touch generally considered the most pleasant (Croy et al., 2017; Sehlstedt et al., 2016). This can impact touching behaviour: people spontaneously stroke others at CT-optimal speeds (Croy et al., 2015) and rate vicarious touch as most pleasant when applied in areas with more CT receptors (Walker, Trotter, Woods, & McGlone, 2017).

In addition to the type of touch, the toucher identity influences the perceived pleasantness of social touch even when touch kinematics are kept constant (Gazzola et al., 2012; Nummenmaa, Tuominen, et al., 2016). Information about the social relationship with the toucher is so intrinsic to the experience of the touch that information about the toucher is represented already from the primary somatosensory cortex (Gazzola et al., 2012; Study IV). However, since the classification accuracies were not consistently higher for comparisons with larger differences in pleasantness ratings, it is likely that the relationship-specific neural correlates relating to social touch do not singularly depict differences in the pleasantness of those touches (Study IV).

The modulating role of pleasantness on social touch is also reflected in TAMs. Those locations, where touch allowances varied the most throughout the social network,

correlate significantly with the areas, where touch is considered to be the most pleasant (Suvilehto et al., 2015; Walker et al., 2017). Furthermore, women both find CT-optimal touch more pleasant (Croy, D'Angelo, & Olausson, 2014) and allow touch and are allowed to touch in larger areas than men. And while pleasantness and emotional bond are very strongly correlated, both pleasantness and emotional bond independently modulate the touch allowances. There seems to be an interplay between the dyadic relationship, how pleasant a touch from a person feels, and how large touch allowances this person is afforded.

5.2 Social touch in different cultures

The samples from six different cultures used in Studies I and II allow us to compare social touching in different cultures in more detail than has previously been possible. This is the first data set inspecting the acceptability of touch in the whole social network and spanning both Western European and East Asian cultures.

5.2.1 Similarities in the studied cultures

In the current studies, the European and Asian cultures had highly similar topographies for acceptable touch by different members of the social network. This is somewhat unexpected based on earlier findings that both the number of touches (Dibiase & Gunnoe, 2004; Jourard, 1966; Remland et al., 1995) and the body sites touched in particular situations (McDaniel & Andersen, 1998) are modulated by the culture of the interactants.

Indeed, traditionally cultures have been indicated as being 'contact' or 'non-contact' with respect to social touch. Areas closer to the equator have historically been considered high touch and Western and Northern cultures considered low touch (E. T. Hall, 1969). We found no evidence of this. In fact, Finland and Russia, the northernmost of the countries participating in the body mapping studies, were the countries with highest TIs, i.e. the most accepting of social touch. This is somewhat corroborated by studies on interpersonal distance. While interpersonal distance with strangers is smaller in countries that are warmer, the effect is reversed for interpersonal distance with a close person (Sorokowska et al., 2017).

The correlation between Touchability Index and emotional bond were essentially identical in the studied cultures. The slope, i.e. increase in TI per additional unit of emotional bond, is effectively the same in all of the six studies Western and Asian cultures. Indeed, the intra-cultural individual differences were far greater than average intercultural differences.

5.2.2 Differences in the studied cultures

The most salient intercultural difference for the association between emotional bond and TI was the differences in the intercepts. The intercept can be interpreted as the baseline touchability of a culture, i.e. how much is a stranger allowed to touch. Since strangers are most likely to be touched for greeting and parting, it is feasible to assume that the differences in the intercept depict the cultural differences in ritualistic touch. Different cultures engage in different types of ritualistic touch, particularly for greeting

(Firth, 1972) and parting (McDaniel & Andersen, 1998). For example, the standard greeting in Japan is a polite bow, in Finland it can be a firm handshake or a warm hug, and in France and Italy, especially between female individuals, it is a kiss on the cheek.

These differences are also observed in the cultural average TAMs, in particular with respect to strangers (Figure 19). For example, in the comparison between Japanese and British respondents, there is a statistically significant difference in the touchability of hands for male strangers (Figure 10). Similarly, the British allow female friend, female cousin, and aunt to touch their cheeks more than the Japanese do. It is likely that both of these differences can be attributed to the differences in greeting styles: the handshake is a more widely used greeting in the Western countries than in Japan, and cheek kisses, particularly between female members of the social network, have grown in popularity in the UK (K. Fox, 2004).

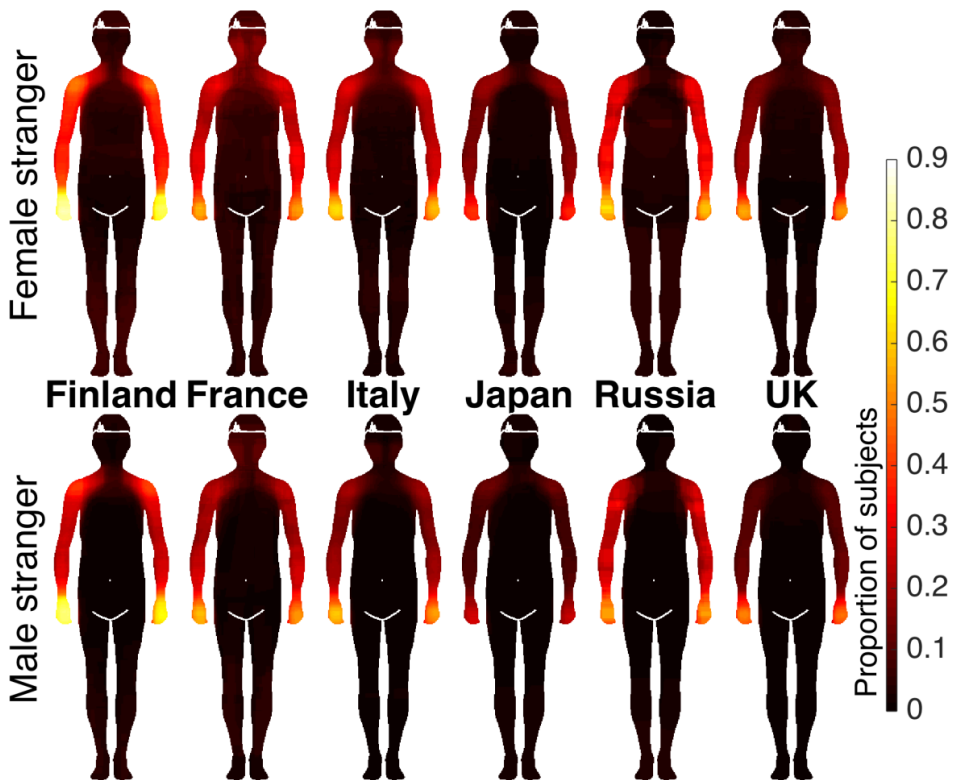


Figure 19. Touch area maps for ventral surfaces of strangers in the six cultures from Studies I and II. Colour bar indicates the proportion of respondents who find that it would be acceptable for a female (top row) or a male stranger (bottom row) to touch them in that area. Notice that touch on hands is less acceptable in Japan than the European cultures, and that French and Italian strangers also have some acceptability on cheeks where other cultures have none. These differences could be explained by differences in ritualistic touches.

5.2.3 Why did we find more similarities than differences?

These cultural differences highlight how culture can modulate the TAMs and TIs to some extent. However, we found much more similarities than differences between these six cultures. This was unexpected, since previous research has suggested that there should be much larger differences between cultures.

This discrepancy might be partially explained by the fact that cultural differences in attitudes toward touch seem to be more pronounced in public spaces and with more distant relations. According to a recent study, while culture can have an impact on the acceptability of touch in public spaces and with non-close others, the cultural attitudes towards touch with close others (such as family members) and at home were very similar in stereotypically ‘high contact’ and ‘low contact’ cultures (Burleson, Roberts, Coon, & Soto, 2018).

The effect of culture has probably been overstated by earlier observational studies due to the limitations imposed by the research method. A lot of the intercultural research has been observational and conducted in public spaces (Dibiase & Gunnoe, 2004; Jourard, 1966; McDaniel & Andersen, 1998; Regan et al., 1999; Remland et al., 1991, 1995), where cultural differences are most pronounced (Burleson et al., 2018). In contrast, in Studies I and II we asked the subjects to report where they found touch acceptable in “different everyday situations” without specifying the context. This may have highlighted the similarities in the cultures, rather than the differences.

When travelling to a distant country for a short trip, it can seem like the way social touch is used at the destination is very different than the way social touch is used at one’s home country. This might be due to the difference between touch in public spaces and distant others and touch at home and with close others. While attitudes towards touch and similar measures (for example, preferred interpersonal distance) vary as a function of toucher, these effects disappear or are smaller with respect to individuals closer in the social network (Burleson et al., 2018; Sorokowska et al., 2017). As tourists, we rarely get to observe or actually experience, for example, touching within a family or at people’s homes.

It is also possible that despite similar self-reported touch allowances, there may be dramatic cultural differences in the actual touching *behaviour*. From the current data we cannot tell how well these hypothetical touch allowances translate into real touching behaviour. However, as discussed in Section 1.2.2, measuring real-life touching behaviour is not trivial.

5.3 The role of touch in social bonding

Social touching correlates with relationship satisfaction in romantic relationships (Gulledge et al., 2003; Muise et al., 2014) and it can even causally improve relationship satisfaction in romantic relationships (Floyd et al., 2009). Even behaviour as primitive as sexual intercourse includes superfluous touching in humans. While some amount of touching (particularly of the core erogenous zones) is necessary for sexual arousal and release, the desired extent of touching while having sex with a partner far exceeds these core erogenous zones (Study III). A possible explanation for this is that stimulating extended erogenous zones during sex with a partner might promote other, non-sexual aspects of the partnership. In particular, in the light of other studies outlined in this Thesis, it seems likely that this touching over extended body areas during sexual intercourse could promote pair-bonding.

The current results show that similar to romantic relationships, social touch correlates with emotional closeness in all layers of the social network. In addition to causally impacting romantic relationships, social touch can increase pro-social behaviour with

strangers (Segrin, 1993). Therefore, given the causal impact of touch with both the individuals closest to us (romantic partner) and those furthest from us (stranger), it seems possible that the role of social touch in establishing and maintenance of social relationships also extends to the rest of the social network.

In the modern world, where it is not unusual for close others to live far apart (Jo et al., 2014), it is relevant to know whether social touch reflects the social relationship or frequency of contact. Touchability of a given region is only modestly correlated with frequency of contact with the toucher (Figure 9). Therefore, it is unlikely that the touch allowances reflect “exposure” to an individual but rather, they seem to indicate the strength of the dyadic relationship. Moreover, touch allowances are malleable over the course of a relationship. This is true both within a relationship category and as the dyadic relationship changes. For example, closer friends have higher TI than more distant friends (Figure 20). Moreover, individuals’ touch allowances can change as a result of a change in the dyadic relationship. Romantic partners, whom we generally allow to touch us in most areas, have at some point been strangers. Friends, who are also allowed to touch as much bodily areas as primary family, are likely to have been acquaintances at some point. This all speaks to the dynamic nature of the touch allowances. Thus, the changes in how social touch is used does reflect, and can potentially impact, how the relationship itself changes.

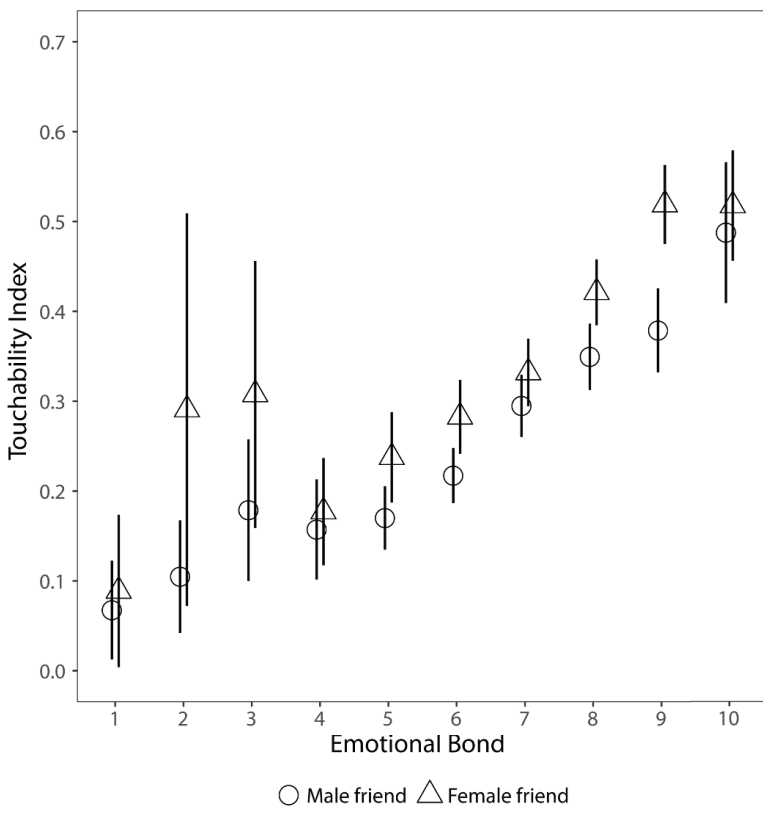


Figure 20. Average TI for male (circle) and female (triangle) friends at each level of emotional bond. Emotional bond scale from 1 (no emotional bond at all) to 10 (strongest possible emotional bond). Data are averages over all six cultures, error bars depict the 95% confidence interval.

Finally, if social touch is related to the establishment and maintenance relationships due to biological factors, one could assume it to occur similarly in different cultures. Indeed, as discussed in Section 5.2, both the TAMs and the association between TI and emotional bond are remarkably similar in different cultures. Together, these findings suggest that social touch in humans is unlikely to be purely culturally normative behaviour but might rather represent biologically based behaviour.

Another argument supporting the view of biologically based social touching comes from non-human primates. More frequent grooming between pairs of individuals is linked to 'friendship' in non-human primates (Dunbar, 2010). More generally, the time spent grooming is correlated with the group size in different species of primates (Lehmann et al., 2007). These findings on how primates use grooming to establish and maintain social relationships corroborate the current data from humans.

5.4 Limitations and future directions

Studies I-III are based on self-reported allowances or experiences during imagined touch by someone. The results revealed that social touch allowances are relationship-specific. Studies I and II asked about where subjects would allow other people to touch them, but not vice versa. We chose this direction, because we wanted to inspect how people experience touches. Nonetheless, because each touch is felt by both the toucher and touch recipient, it is important to also consider the other direction, i.e. where people believe they are allowed to touch other people.

In same-sex relationships between people of similar age, the touch allowances one assigns for others is very close to touch allowances one assumes for others (Tomita, 2008). Most deviations from this pattern indicated that subjects were more accepting of being touched than they assumed others to be (Tomita, 2008). However, it is not clear if this extends to other relationships. Therefore, it would be important to conduct similar studies on subjects' expectations of where they are allowed to touch different members of their social network.

Moreover, we cannot be sure how the self-reported touch allowances translate into real-world touching behaviour. The connection between comfort with touch and touching behaviour has some experimental support. There is some evidence that at least in Japan the touch allowances from the current studies are concordant with self-reports of where people have been touched by their parents or friends (Barnlund, 1975). More generally, previous research indicates that individuals reporting more comfort with touch were more willing to engage in situations they knew would contain touching people (Fromme et al., 1989).

It is likely that touch allowances and touching behaviour correlate at least to some extent. For example, being comfortable with touching another person for more reasons is likely to lead to more touches (assuming you see them in situations where e.g. helping or consoling is relevant). In one study, subjects were asked to keep a log of the touches they received over three days (Jones & Yarbrough, 1985). In that sample, greeting and parting touches only accounted for 10% of the reported touch occurrences (Jones & Yarbrough, 1985). Moreover, many of the touch types, such as touches signalling inclusion, affection, and appreciation, mainly occurred between close relationships (Jones & Yarbrough, 1985). This suggests that more reasons to touch a person

would also translate to more actual touches. However, more research is needed to establish the relationship between touch allowances and real-life touching behaviour.

While the current studies mainly discuss averages or proportions, it should also be noted that there are large individual differences in touch allowances. Individuals also differ in the what kind of touch they experience as pleasant (Luong, Bendas, Etzi, Olausson, & Croy, 2017), and how pleasant they find touch in the first place (Sailer & Ackerley, 2017). So, while we find there to be very little (statistically) different between the countries, it is possible that this finding is driven by the large differences within a culture, rather than the absence of differences between cultures.

The most interesting finding of this thesis is that there is a clear correlation between emotional bonding and social touch (Studies I & II), potentially modulated by pleasantness of touch. However, these data do not give any indication as to the direction of the causality. We do not know whether touch allowances (body areas and reasons for touch) increase when we start liking people more or is there also a reverse effect where by touching we can make people like us more. It would be extremely interesting to try to determine experimentally, whether this is the case. Research in this direction has potential to inform policy making and it would be especially relevant in the modern age of digital communications.

6. Conclusions

The studies outlined in this Thesis highlight central role of social touch in adult human relationships. Touch is used in relationship-specific manner, and information related to social touch is processed already in the early sensory cortices. These findings emphasise the importance of relationship-specificity in the perception and use of social touch. The current findings also reveal associations between the acceptability of touch, the emotional bond with the toucher, and the pleasantness of touch. Specifically, both the emotional bond and the pleasantness independently explain some of the variation in the touchable body area. Moreover, the current findings indicate that the social touching is culturally universal, and culture-specific variation is minimal. This suggests that social touch is likely to be biologically determined, rather than culturally normative behaviour. The linear association of acceptability of touch with the strength of the emotional bond suggests that touch allowances are an indication of the dyadic relationship. The use of touch during sex and earlier experimental work in romantic couples suggests that touching can also be used to modulate the emotional bond. Combining the current results about the gradation of social touch across different relationship with results on the causal role of touch in improving romantic relationships suggests that humans use social touch in maintaining and/or establishing social relationships similar to non-human primates.

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