Chapter 8
Psychophysical Assessment of the Sensory and Affective Components of Touch

Steve Guest and Greg K. Essick

Abstract In this chapter, we address two issues. Initially, we consider how to assess the sensations and emotions that occur through touch. This is not a trivial problem, for there exists a wealth of potentially relevant language that one might use to construct appropriate psychometric instruments. After reviewing the limited number of prior tactile lexicons, we illustrate a method by which we have developed a new lexicon for touch. This 'Touch Perception Task' allows the assessment of relevant sensory and emotional components of perception. In the subsequent part of the chapter, we review two classes of devices for the study of touch. These devices either allow tactile stimuli to be delivered in a highly controlled manner, or allow the assessment of the physical interactions between skin and stimulus during tactile perception. The former robotic stimulators are of particular relevance to the study of C-tactile afferents, because they allow stimuli to be presented to hairy skin with velocities that are well- or ill-suited to stimulate such afferents. The other class of force-plate devices tends to be limited to assessing finger–surface interactions, which do not involve C-tactile afferents. However, active touch using the fingers is an important human behavior, which can certainly be replete with emotion. As such, it is important to reconcile C-tactile mediated affect, and the affect that derives from touch devoid of these afferents. Robotic and force-plate devices will both be of utility in this respect.

Keywords Affect • Emotion • Lexicons • Mechanical events • Perceptual space • Review • Sensation • Stimulus parameters • Touch

---

S. Guest, B.Sc, P.G.Dip., Ph.D., CertHE (✉)
School of Social Work, University of North Carolina at Chapel Hill, NC, 27599, USA
e-mail: Steve_guest@unc.edu

G.K. Essick, D.D.S., Ph.D.
Prosthodontics, and Regional Center for Neurosensory Disorders, School of Dentistry, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-7455, USA
e-mail: Essick@email.unc.edu

H. Olausson et al. (eds.), *Affective Touch and the Neurophysiology of CT Afferents*, DOI 10.1007/978-1-4939-6418-5_8

Introduction

Sensations and emotions are distinct aspects of perception, and both are needed to fully describe a perceptual experience. Sensations—described by sensory words—are typically closely tied to definable, measurable stimulus properties. For example, the sensory word *roughness* has been shown to be associated with the magnitude of surface variation (Bergmann Tiest and Kappers 2006) and with timewise variations in friction between an exploring fingertip and underlying surface touched (Smith et al. 2002a). Similarly, for fluid-coated surfaces, perceived *viscosity* has been linked to the friction and vibrations that are recorded during a fingertip's exploration of the lubricated surface (Guest et al. 2012a). Although the link between each and every sensory word and its instrumentally defined basis is not understood, the potential exists to forge all such relationships. In contrast, emotions—described by emotional words—describe feelings that accompany sensations. Such words are not necessarily linked to instrumental measures in straightforward manner. For example, the feeling of *pleasure* can arise from very disparate physical stimuli. The sensations evoked by a physical stimulus may also be influenced by things other than the stimulus itself, such as global aspects of the perceiver's emotional state (viz. mood). In this way already present, or transiently occurring emotions, can alter the behavioral response to a physical stimulus, a critical component of commercial advertisements for example (Holbrook and Batra 1987; Laros and Steenkamp 2005).

This distinction between sensation and emotion is supported in validated psychometric tests (Melzack 1975; Melzack and Torgerson 1971), in social psychology (Osgood 1952, 1966; Osgood and Suci 1955), and also by neurophysiology. The latter work suggests that the sensory and emotional components of perception may be rooted in their transduction by different types of skin mechanoreceptor (Löken et al. 2006, 2009; McGlone et al. 2007, 2012; Olausson et al. 2002, 2008a, b). Specifically, it has been found that the magnitude of activity in low-threshold, unmyelinated mechanosensitive afferents, present in hairy skin, is closely associated with psychophysical ratings of pleasantness. That is, stimuli which strongly elicit C-tactile (CT) activity are expected to be judged as especially emotionally salient.

This discussion arrives at the purpose of the first half of this chapter, namely how best to assess the sensations—and especially—the emotions that occur through touch. It is not a simple task to relate afferent activity to perception if in the first place it is not clear what aspects of perception must be queried. For example, although CT afferents are often spoken of in the general context of 'pleasantness' (McGlone et al. 2012), it is not clear that pleasantness is the best descriptor of what is conveyed by CT activity; there may be more pertinent emotions. Pleasantness has been the default emotional tactile attribute studied from the earliest studies (Major 1895; Ripin and Lazarsfeld 1937) through to the present day (McGlone et al. 2012). However, although pleasantness is certainly important, it is not necessarily the 'best' or most veridical affective attribute for study; nor does the 'pleasantness' of something describe the full emotional experience that may occur during touch. The first half of this chapter highlights the incomplete picture that studying purely pleasantness might provide, and details the development of tools that allow a more complete assessment of the emotional and sensory aspects of touch. Such tools allow presumptive CT afferent activity or indeed any other emotionally salient complex sensory input to be probed psychophysically with improved precision.

The second half of this chapter addresses tools that allow for better assessments of tactile hedonic perception to be made. In this text, we illustrate the development of devices that allow stimulus parameters to be tightly controlled for the application of stimuli to the skin. In particular, we note the development of a Rotary Tactile Stimulator (RTS; Essick et al. 2010) which can present materials to the skin with controlled speed, force, and direction of delivery. This is of clear utility in characterizing CT afferent activity in response to touch. Indeed, the RTS has been used in several recent microneurography studies to provide precise stimulus control (Löken et al. 2009, 2012). We also describe recent developments of devices that can characterize what occurs during free, active touch, specifically in terms of the forces and other 'mechanical events' that occur at the fingertip during touch. These devices are quite unlike those such as the RTS, which have traditionally been tailored so that an observer passively receives a carefully controlled stimulus. Devices that can characterize active touch allow for more ecologically valid experiments in emotional touch to be conducted.

Lexicons for Sensory and Emotional Touch

Language is the primary means by which we express our reactions to the things we touch and the things which touch us. In this respect, one might seek to assess a touch experience by asking the receiver of the touch to freely generate all words of relevance to the touch (e.g., the touch felt *soft*, *smooth*, *sexy*, etc.). However, freely generated, subjective descriptions of a touch experience make for poor data. This is for a few reasons: First, any individual might neglect to report a sensation or emotional reaction, even if it pertained to the touch. For example, the word *soft* might not be generated, but that does not mean the touch was not felt as *soft*. Second, the degree to which any word applied to the touch is not obtained from simple word generation. For example, if the touch indeed felt *soft*, <u>how</u> soft did it in fact feel? Third, the nature of each word is ambiguous; one cannot simply intuit the nature of a generated word, or rely on dictionary definitions to obtain robust data about touch. For example, does the word *silky* denote a sensory percept, or does it invariably carry with it emotional connotations? To what extent is *silky* synonymous with words such as *smooth* and *satiny*? Intuition does not lead to a reliable answer.

One way of characterizing a touch experience is to obtain a list of words which is stringently derived to allow a tactile, or other specific perceptual experience to be fully and accurately described (Bhushan et al. 1997; Osgood 1952; Stevenson and Boakes 2003). Such a set of words is what we term a *lexicon*. Until recently no attempt had been made to derive a touch lexicon, although lexicons for other modalities of perception have been reported previously (Bhushan et al. 1997; Dravnieks 1982, 1985; Harper et al. 1968). These are detailed below; they provide a context and base methods relevant to our development of a touch lexicon, which we describe in detail later.

Nontouch Perceptual Lexicons

The practical need for lexicons is universal across our various sensory modalities. For example, language to precisely describe odor perception is of utility for the evaluation of perfumes and beverages containing volatile odorants (Stevenson and Boakes 2003). A lexicon for (visual) texture perception could potentially allow spoken interactions with computer graphics systems for rapid generation of visual elements (Bhushan et al. 1997), for example, 'put a *granular*, *woven* texture on the red cube.' Similar arguments can be made for the utility of lexicons for audition and taste. Accordingly, lexicons have been developed and reported for some nontactile perceptual tasks. The nontactile lexicons are directly relevant to a touch lexicon: Their research has established basic principles for lexicon development, demonstrated important properties of descriptive word use and illustrated the practical utility of lexicons.

Any lexicon development must begin with the collation of an initial candidate set of all words that might be of relevance to the task. This is followed by culling these words by some method to product a final, manageable set of words. This final set forms an initial lexicon, which can be used as-is, or refined further. The overall idea here is simple, but there is no single method by which words might be selected and then culled. The initial candidate set of words is invariably subjective to a large extent, being necessarily produced using dictionary and literature searches, and introspection. For example, the (visual) texture lexicon (Bhushan et al. 1997) began with a candidate set of 367 texture-related words which were culled by removal of terms referring to interactions between light and a surface (e.g., *transparent*), and by removal of words used infrequently in American English (e.g., *ruched*). This led to a final lexicon of 98 words. Odor lexicons have tended to move toward a larger set of words over time and according to empirical needs. So, an odor lexicon of 44 words was proposed in the 1960s (Harper et al. 1968), later being expanded to a candidate set of over 800, which was reduced to 146 by 1982 (Dravnieks 1982, 1985). The rather labile nature of odor lexicons highlights that establishing a balance between a manageable number of words in a lexicon and the completeness of the lexicon is not an easy task.

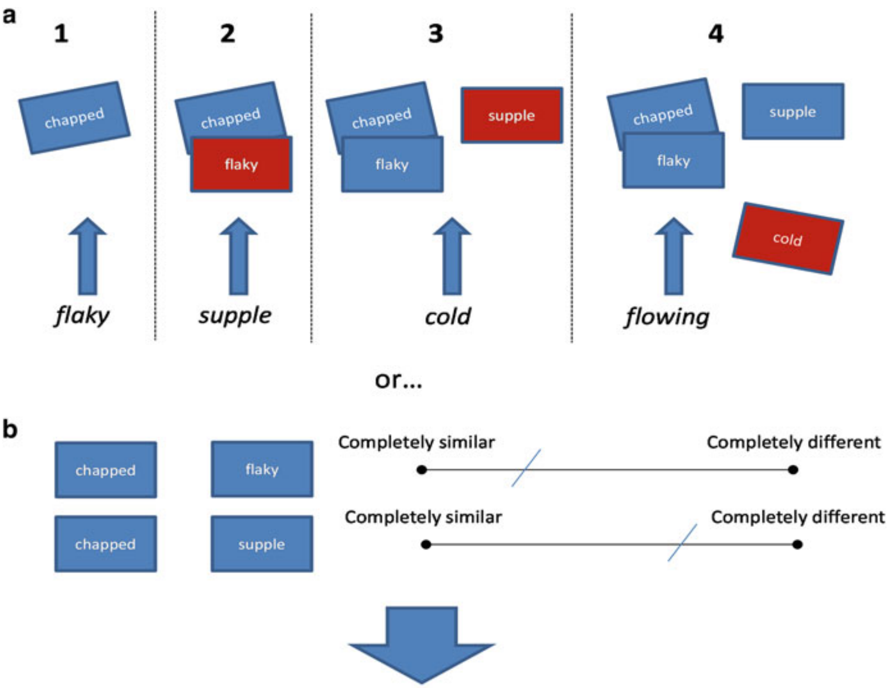
A more positive finding from the prior work is that descriptive language appears stable. That is, the degree to which a given descriptor applies to a stimulus is, on average, consistent. This was shown via empirical testing using a test set of odorants, some of which were quite perceptually similar (Dravnieks 1982). In simple terms, if an odorant is well-described as *sweet* and *yeasty*, then it will always be well-described by those words, at least over a sufficiently large sampling of respondents. Similar results have been shown for the visual texture lexicon by testing associations between actual, empirical textures and the texture lexicon words (Bhushan et al. 1997). Providing a set of texture lexicon words that applied to a given texture allowed the applicable texture to be successfully selected from a set of candidate textures. For example, one could correctly find a texture specified as *granular, well-ordered,* and so forth from a set of various example textures. It is reasonable to expect language to have similar properties over all sensory modalities, suggesting that a touch perception lexicon should also have a foundation in suitably stable descriptive language.

Semantic Relationships within Lexicons

The development of any lexicon would ideally include not only the production of a set of descriptive words, but would also quantify the semantic relationships among the words. The idea here is that any word could potentially be placed within a space, defined by orthogonal dimensions, where each dimension could be labeled with distinct concept or perceptual quality. Such a space is in essence a map, with cities replaced with words, distances between words representing their dissimilarity. For example, taking the words *slick* and *slippery*, how similar is the meaning of these words? Is the difference between *slick* and *slippery* akin to the distance between *sticky* and *glutinous*? A more sophisticated question might then be; are *smooth* and *slippery* words that simply describe different extents of some underlying quality, such as *smoothness*? The answers to these questions potentially assist lexicon development in allowing a principled culling of words. For example, a semantic map of words essentially allows the definition of the degree to which words are empirically synonyms (or empirically exceedingly different) to be defined. Neighboring words could potentially be quite different from dictionary-based synonyms.

The development of semantic maps may seem like a fairly abstract problem, but the actual process by which such maps are constructed is simple. Numerous experiments have produced similar maps, but for actual, physical materials assessed by touch. These experiments therefore provide maps of stimuli in a perceptual space, as opposed to maps of words in a semantic-perceptual space. However, perceptual map development is essentially the same, regardless of whether physical material or words are assessed. This development process is shown in Fig. 8.1 giving words as example stimuli.

Each experiment's first task has been to obtain measures of the dissimilarity of the different materials, via either free-sorting tasks (Fig. 8.1a) or via pairwise comparisons of stimuli (Fig. 8.1b). In the former, participants simply arrange stimuli into groups that 'belong' together in some (usually undefined) sense, with dissimilarities being defined based on group memberships. In the latter, participants rate each and every pair of stimuli in terms of how dissimilar the members of each pairing are felt to be. Regardless of how dissimilarities (Fig. 8.1c) are obtained, they are then analyzed using Multidimensional Scaling (MDS), a technique that explicitly produces an *n*-dimensional map that best replicates the empirical distances among items. These methods have established that (nonfluid) materials, such as manufactured textiles or natural materials, are well described by approximately three orthogonal perceptual dimensions (see Okamoto et al. 2013 for a review), namely, *Rough–Smooth* (Bergmann Tiest and Kappers 2006; Hollins et al. 1993, 2000; Na and Kim 2001; Picard et al. 2003), *Hard–Soft and a* less clearly defined tertiary dimension, perhaps consisting of *Springy-Inelastic* (Hollins et al. 1993), or *Sticky–Slippery* (Fig. **8.2**). For fluids, such as skin care products, quite different dimensions have been suggested, such as a primary component consisting of a combination of *residue*, *stickiness,* and *gloss* after application (Almeida et al. 2008). This illustrates another difficulty in formulating a successful touch lexicon, namely that it would need to be capable of describing all tactile experiences, including those that arise from the touch of both dry surfaces and wet surfaces.



c

	chapped	flaky	supple	cold
chapped	-			
flaky	0	-		
supple	1	1	-	
cold	1	1	1	-

Fig. 8.1 The basic procedures used in perceptual scaling experiments. First, the dissimilarity of stimuli is assessed, such as by freely sorting stimuli (**a**), or by making pairwise ratings of stimuli (**b**). This allows a dissimilarity matrix to be produced (**c**), in this case that shown is as derived from (**a**). Typically, the matrix is obtained by averaging responses made by many participants

Note that none of these touch-based studies explicitly considered the use of language in perception. Each study used sorting methods applied to physical materials with the axes of the perceptual space being labeled afterwards, based on the experimenters' intuitions or sometimes more sophisticated statistical methods; thus, none of these studies provided a lexicon. However, the studies did suggest some of the more important percepts, which should thus be included within a touch lexicon. Or, put another way, if a proposed lexicon lacked language related to roughness or smoothness, the lexicon would likely be incomplete. We know this because roughness and smoothness are unambiguously important aspects of touch perception.

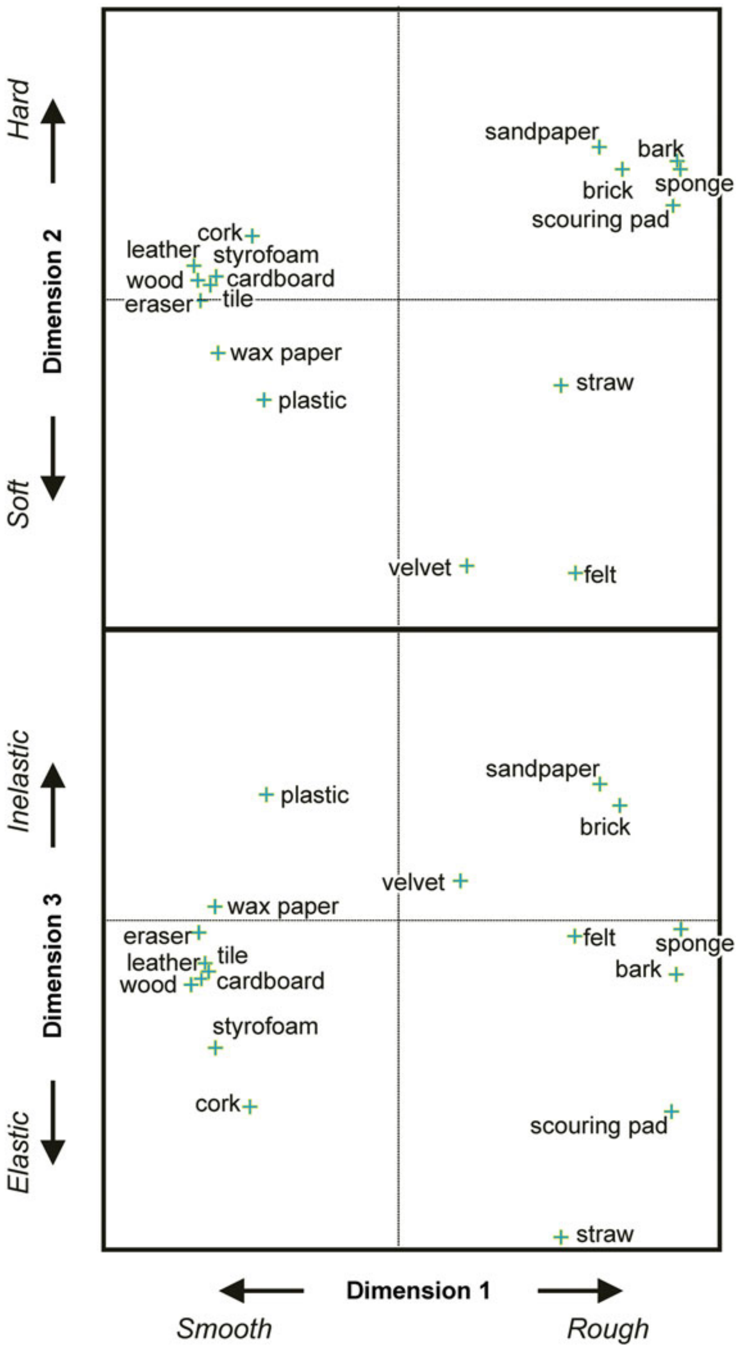


Fig. 8.2 The perceived similarities of different stimulus materials can be represented in *n*-dimensional perceptual spaces. Shown is a three-dimensional space derived by Hollins et al. (1993), depicting the perceptual distances for 17 common textured materials. Each dimension (i.e., axis) broadly represents a distinct type of perceptual change, for example, the first dimension encompasses stimuli varying from *smooth* to *rough*

Semantic mapping has been applied to some of the nontactile lexicons. For example, the 98 ‘final’ words of the visual texture lexicon (Bhushan et al. 1997) were used in a sorting task, wherein participants sorted words into ‘similar’ groups, just as in the tactile material studies described above. Subsequent MDS revealed that in a three-dimensional space, explaining 82 % of the variance in word distances, the three axes were plausibly labeled as *Repetitive* versus *nonRepetitive*, *Linearly* versus *Circularly oriented* and *Simple* versus *Complex*. In this case, the semantic space was not used to reduce the lexicon further in size, although the space (and a related clustering analysis) was used to define which of a series of broader concepts a word described, such as which of the 98 words referred to the concept of *Granularity*. This allowed lexicon words to be assigned to groups for the purpose of scoring lexical ratings of textures.

Sensation Versus Emotion

The sensory aspects of touch have tended to be studied in far more depth than the emotions that arise from touch. However, the emotional qualities of any perceptual experience are very important. Touch has long been known to be critical in the physical (Meaney et al. 1991; Meerlo et al. 1999), social, and cognitive development of humans and other primates, possessing great emotional potential (Björnsdotter et al. 2000; Diamond and Amso 2008; Harlow 1958; Montagu 1986). Ongoing work into the role of CT mechanoreceptors suggests these are one means by which socially meaningful touch might be initially transduced (Löken et al. 2006, 2009; McGlone et al. 2007, 2012, 2014; Olausson et al. 2002, 2008a, b). This foundational role of touch aside, we clearly have an emotional response to many things we touch in daily life. Indeed, much commercial product development is tailored toward optimizing emotional feelings that arise from product use (Foxall and Greenley 1998; see Spence and Gallace 2011 for a review), especially in the context of foods and beverages (King and Meiselman 2010; Manzocco et al. 2013).

Just as prior work has determined the perceptual dimensions for the assessment of physical materials, so social psychology has suggested that any emotional experience is embodied with certain amounts of three independent qualities, namely *Pleasure*, *Arousal,* and *Dominance* (Osgood 1952; Osgood and Suci 1955; Russell and Mehrabian 1977; Russell and Steiger 1982). Figure 8.3 shows the spatial arrangement of some emotional terms, in much the same way as the physical materials shown in Fig. 8.2. The locations of the emotional words in the figure were derived from ratings made by people of actors depicting a single emotional state, for example, “To what extent does the actor appear *happy* versus *sad*?” The ratings were then analyzed in the same manner as the physical material data described earlier.

This background illustrates that the importance of the emotional qualities of experience have long been recognized, as has knowledge of the structure of emotional space in a wider context. In the specific context of sensory perception, the structure of emotional space has been quite sparsely studied, although emotional words have been used frequently in perceptual studies, as will be illustrated below.

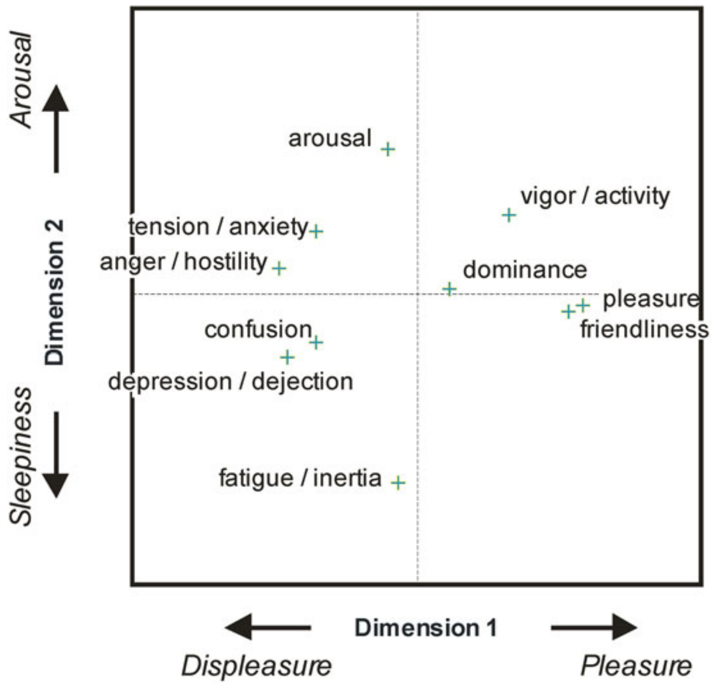


Fig. 8.3 Similar to physical materials, (emotional) words can be positioned in a semantic space that shows their similarities. The first two dimensions of the emotional space of Russell and Steiger (1982) are shown

Emotional Words in Perception

The words that describe emotional states in general (e.g. Fig. 8.3) are not necessarily the same as those used to describe tactile related emotions, and even words common to general emotional states and tactile-perceptual derived states will not necessarily be equally salient.

Pleasantness and allied percepts (e.g., comfort, Cardello et al. 2003; Guest et al. 2009) have been assumed to be important in tactile perception, an assumption that stretches back into the late 1800s (Major 1895) and continues to this day (Essick et al. 1999, 2010; Picard et al. 2003). Ratings of tactile pleasantness have often been shown to vary among materials (Essick et al. 1999, 2010). Additionally, pleasantness has clear face validity. However, it has never been explicitly tested whether pleasantness is the most salient emotional response to touch.

In counterpoint, the term *pleasantness* appears congruent with the primary dimension of general emotional experience, namely *Pleasure* (Fig. 8.3). Therefore, although the ubiquity of pleasantness did not arise though principled study, it happens that pleasantness is likely to be a very important tactile emotional quality given the importance of pleasantness in nontactile emotional responses.

Recently, an emotional lexicon (EsSense Profile) designed for the oral perception of foods has been reported, consisting of 39 words (King and Meiselman 2010). This lexicon was developed considering affect divided into three subsets: *attitudes*, *emotions,* and *moods*. Attitudes were defined as basic evaluations, such as “I like cheese.” Emotions were defined as brief, intense, and focused on some specific object, such as “I hate cheese.” Moods were defined as enduring, gradually formed, and not focused on a specific referent, such as “I feel content.” Using three subsets, by referring to prior work on attitudes, emotions, and moods (e.g., the Profile of Mood States, McNair et al. 1971), the lexicon was produced.

Although this lexicon was intended for the assessment of foods, the emotional words selected are by no means exclusive to food perception (Table 8.1). Further, food perception has a strong tactile component, suggesting that this lexicon could inform a more widely applicable touch lexicon. Unfortunately, the words were not characterized in terms of their underlying perceptual structure; each word was grouped a priori as positive, negative, or uncertain. That said, the word selection procedure was reasonably principled, being based on the use of consumer-derived data to cull the lexicon. Therefore, a primary issue with King and Meiselman’s lexicon is that it might not sample any underlying emotional–perceptual space well. Of course, it was—and remains—unclear as to how many underlying emotional dimensions exist with respect to an oral–emotional space. Indeed, until the development of the Touch Perception Task (see section below), it was unclear as to how many emotional dimensions exist with respect to tactile perceptual space in general, what emotional words describe those dimensions, and in what way such emotional dimensions are related to the established sensory dimensions. However, it is quite clear and implicitly understood that any touch lexicon must

Table 8.1 39 words that form the EsSense profile, designed specifically for assessing the emotions associated with foods

Active	Glad	Pleasant
Adventurous	Good	Polite
Affectionate	Good-natured	Quiet
Aggressive	Guilty	Satisfied
Bored	Happy	Secure
Calm	Interested	Steady
Daring	Joyful	Tame
Disgusted	Loving	Tender
Eager	Merry	Understanding
Energetic	Mild	Warm
Enthusiastic	Nostalgic	Whole
Free	Peaceful	Wild
Friendly	Pleased	Worried

incorporate words that describe sensation and emotion if any given tactile experience is to be described fully.

The Development of a Lexicon Explicitly for Touch

With the above context, we decided to produce a lexicon for tactile perception with the express purpose of allowing for the classification of sensory and emotional components of tactile perception. This lexicon was termed the Touch Perception Task, or TPT (Guest et al. 2011). No such comprehensive descriptive scheme for touch had been attempted previously. That is not to say that words of relevance to touch perception were unknown. For example, lists of 'Exploratory Procedures' or (EPs) had been classified and reported (Lederman and Klatzky 1987, 1990), although these were more an attempt to classify the important actions in active touch, rather than classifying the experience of touch in terms of its emotional and sensory content. Hints of other relevant tactile sensory concepts were present in prior tactile perceptual space work (Bergmann Tiest and Kappers 2006; Hollins et al. 1993, 2000; Na and Kim 2001; Picard et al. 2003), but as noted above prior work was of limited help in formulating a candidate lexicon given that it dealt with physical stimuli and not words per se.

We built upon the lexicon development methods not only as described for non-touch modalities, but also incorporating an important concept underlying development of the McGill Pain Questionnaire (MPQ; Melzack 1975, 1987; Melzack and Torgerson 1971). This was the realization that pain can have many qualities ("The pain of a toothache is obviously different from that of a pin-prick…" Melzack 1975, p. 278) which can be conveniently divided into those describing *sensory/discriminative*, *emotional,* and *evaluative* attributes of pain perception. We have described what is meant by the *sensory* and *emotional* aspects of perception earlier. *Evaluative* aspects of perception are those that refer to the significance, importance, or intensity of the sensory experience (i.e., pain, in the context of the MPQ). *Intolerable* is one example of an evaluative word listed in Melzack and Torgerson (1971).

We recognized that nonpainful tactile perception could also potentially be divided into sensory, affective and evaluative aspects. Therefore, combining ideas from prior lexicon development and the MPQ, we selected 262 initial candidate words (Table 8.2) via dictionary search. These were then rated by 49 individuals in terms of the extent to which each was considered emotional, sensory, or evaluative in nature. Ratings were collected using a four-point scale, where a rating of unity denoted the word had nothing to do with the aspect of touch under consideration whereas a rating of 3 or 4 indicated that the word referred moderately or strongly, respectively, to the aspect of touch.

This process revealed a few interesting findings. First, of the 262 candidate words, only 168 referred at least moderately overall to one or more aspects of touch. Second, whereas the MPQ development process upheld a distinction between *sensory*, *emotional,* and *evaluativ*e, the ratings of touch-related words

Table 8.2 262 words chosen as possible members of a touch lexicon

Abrasive	Decisive	Gelatinous	Meaty	Rugged	Taut
Achy	Dehydrated	Gentle	Moist	Sandy	Tender
Airy	Delicate	Glassy	Mushy	Satiny	Tense
Annoying	Demanding	Glossy	Nappy	Scabby	Tension
Arctic	Dense	Gooey	Nice	Scalding	Tepid
Arid	Desirable	Goopy	Nippy	Scaly	Textured
Arousing	Determined	Grainy	Notable	Scorching	Thick
Attending	Diffuse	Granular	Noticeable	Scraping	Thorny
Aversive	Dirty	Grating	Oily	Scratchy	Thrilling
Blissful	Discomfort	Greasy	Oozy	Searing	Tickling
Blunt	Distinctive	Grimy	Overheated	Sensual	Ticklish
Breezy	Distressing	Gritty	Painful	Sexy	Tickly
Bristly	Doughy	Grooved	Parched	Shaggy	Tight
Brittle	Downy	Gummy	Pat	Shallow	Tortuous
Bumpy	Drenched	Hairy	Pebbly	Sharp	Tough
Burning	Dry	Hard	Persistent	Significant	Tranquil
Bushy	Dull	Heavenly	Pert	Silky	Transient
Callous	Effervescent	Horny	Placid	Sinuous	Translucent
Calming	Elastic	Hot	Plastic	Slack	Trim
Chafed	Enjoyable	Hydrous	Pleasurable	Slick	Uneven
Chalky	Erotic	Icky	Pliable	Slimy	Unyielding
Chapped	Evocative	Icy	Plush	Slippery	Vague
Chilly	Exciting	Impacting	Pointed	Sludgy	Velvety
Clammy	Feathery	Important	Pointy	Slushy	Veneered
Clean	Filmy	Indented	Poked	Smear	Vibrating
Clear	Fine	Inflexible	Polished	Smooth	Viny
Coarse	Firm	Intense	Porous	Soapy	Viscous
Cold	Flabby	Irregular	Pounding	Soft	Vivid
Comfortable	Fleecy	Irritable	Powdery	Solid	Warm
Compliant	Fleeting	Irritating	Pressed	Soothing	Watery
Compressed	Fleshy	Itchy	Pressure	Spiky	Waxy
Consequential	Flexible	Jagged	Prickly	Spiny	Weird
Contact	Florid	Leathery	Provocative	Spongy	Wet
Cool	Fluffy	Light	Pulpy	Springy	Wiggly
Cottony	Fluttering	Liquidly	Purposeful	Squeezed	Woodsy
Crawling	Focused	Lively	Raw	Squishy	Woody
Creamy	Fragile	Localized	Relaxing	Steely	Wooly
Creepy	Freezing	Lumpy	Resolute	Sticky	Worn
Crispy	Friction	Luscious	Ribbed	Stringy	Wrinkly
Crumbly	Frigid	Lush	Rigid	Supple	Yielding
Crusty	Frosty	Malleable	Ripply	Sweaty	Yucky
Cushy	Furry	Matted	Robust	Sweeping	Yummy
Damp	Fuzzy	Mealy	Rough	Tactual	
Deadened	Gauzy	Meaningful	Rubbery	Tap	

showed that few tactile words were considered distinctly evaluative. Of the 168 words, 32 were evaluative in nature, but most of these were also considered additionally sensory (5 words), emotional (13 words), or sensory and emotional (6 words) in nature. Furthermore, such words were generally rated as more sensory or emotional than they were evaluative. Of the eight words remaining as predominately evaluative, only *important* revealed itself as strongly and unambiguously evaluative. On that basis evaluative was dropped as an aspect of touch considered during the lexicon development.

To cull the word list further, a dual ranking scheme was used. The sensory and emotional words were placed in order of decreasing sensory or emotional ratings, 'within word' and 'within aspect.' This is illustrated for the sensory words in Fig. 8.4; the same procedure was carried out separately for the emotional words. These ranking schemes considered how each word was ranked within the whole set

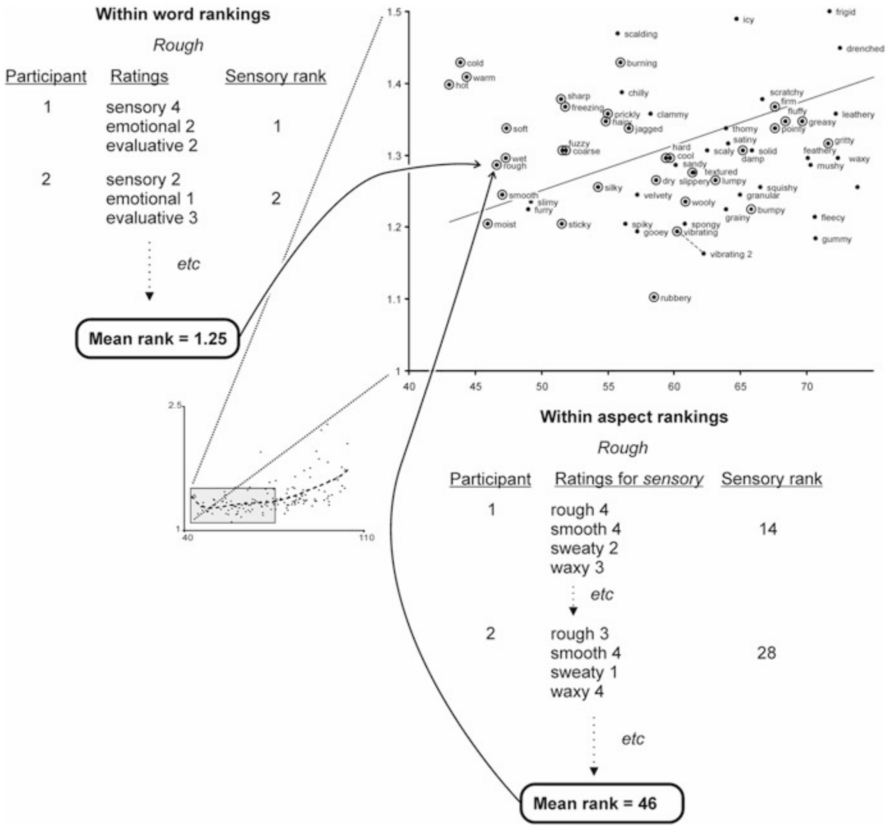


Fig. 8.4 When developing the Touch Perception Task, to form a lexicon of manageable size required choosing the best words from the many available. This was achieved by considering rankings of words in terms of the two schemes shown. The main figure is a subset of a much larger set of candidate words, per the small inset figure. Figure adapted from Guest et al. (2011). *Encircled points* are words that were selected for further consideration following this ranking phase

of sensory or emotional words, and within the three perceptual aspects (i.e., sensory, emotional, and evaluative).

After choosing the best ranked words, 97 words remained for a candidate lexicon, considered too many to be practicable for further study. Therefore a subjective culling was applied, with removal of retained synonyms (e.g., *scalding* and *burning* passed the ranking criteria, but *scalding* was excluded) and terms related to very specific materials (e.g., *furry* was excluded while keeping *fuzzy*). The original list of 262 was now winnowed down to 33 sensory and 16 emotional words.

Finally, similarity judgments of all pairings of the words were obtained, considering sensory and emotional words separately (see Fig. 8.1b, c), allowing perceptual spaces to be found for sensory and emotional words. The sensory and emotional spaces were both considered three dimensional. They are shown in Fig. 8.5.

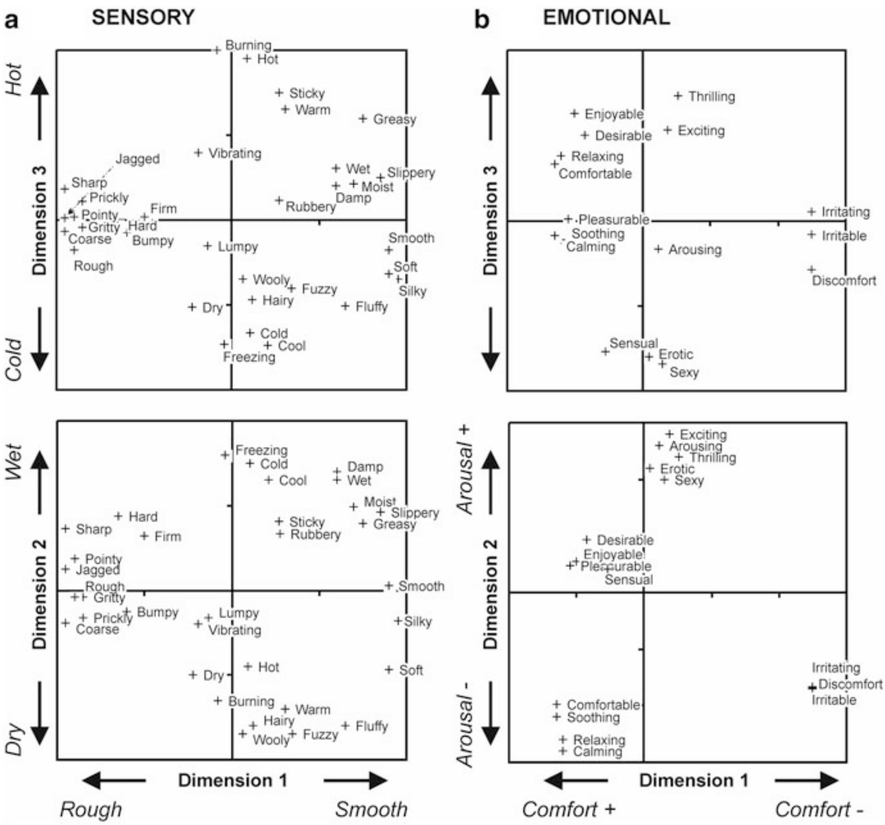


Fig. 8.5 The semantic relationships among sensory (**a**) and emotional (**b**) words pertaining specifically to touch. The third axis of the emotional space was not easily labeled and was considered to denote a difference in emotional quality among words, but possibly could be labeled as varying sensuality or eroticism

On inspection of the sensory word space we suggested the axes could be labeled *Rough–Smooth*, *Dry–Wet,* and *Hot–Cold.* Similarly, the emotional space axes were labeled *Comfort*, *Arousal,* and (more tentatively) *Sensory quality*. The relative locations of words allow one to determine which are similar enough that one or more might be omitted.

The Touch Lexicon in Use

After developing a touch lexicon, it is important to ask whether the lexicon 'works.' That is, does the lexicon successfully allow emotional and sensory responses to tactile stimulation to be assessed? And in the context of this book, do the responses to the sensory and emotional words of the touch lexicon support CT afferents' purported role in emotional touch?

We first used the TPT to collect subjective judgments of textiles stroked across a variety of body sites (Guest et al. 2011). The textiles were typical of those used in prior affective touch work (Essick et al. 1999), for which expected sensory properties were known and pleasantness ratings were available, allowing for some degree of validation of the TPT. The primary analysis method was to decompose the sensory and emotional word ratings of the TPT via Factor Analysis (i.e., the individual attributes of the TPT were not considered directly), although we have in other studies analyzed the individual attributes of the TPT (Guest et al. 2014). Four orthogonal sensory factors emerged describing, in decreasing order of importance, *Roughness*, *Slip*, *Firmness,* and *Pile*. The scores for the different textiles fell as expected within these factors. For example, a coarse hessian (burlap) material was scored as rougher than cotton t-shirt material. Two emotional factors emerged, approximating *Comfort* and *Arousal*. As for the sensory factors, the emotional factor scores fell as expected, although some interesting additional effects were found. For example, although silk was scored as very comfortable, this was far more the case when that material was moved over the finger or forearm as opposed to the underarm.

We subsequently extended this work to the tactile perception of a film surface coated with 15 different fluid skin care products (Guest et al. 2012b), again finding clear TPT-derived differences among the fluids, in this case the TPT attributes decomposing into five orthogonal sensory factors approximating *Wetness*, *Texture*, *Slickness*, *Silkiness,* and *Viscosity*—factors quite different in nature to those found for the assessment of textiles. In contrast, the factors describing the emotional experience of touch were similar for the tactile experience of fluid and textile stimuli (Guest et al. 2011, 2012b). However, in neither case did emotional experience of *Dominance* emerge, despite the common appearance of this factor in many social contexts. Perhaps, *Dominance* is only of consequence in interactions between, or assessments of, other humans (perception of body posture, Mehrabian 1970; perception of facial expression, Osgood 1966). In contrast, it seems that *Pleasure* (or *Comfort*) and *Arousal* are universal dimensions of any emotionally based judgment, emerging for social situations and for assessments of inanimate objects (i.e., textiles and skin creams).

Regarding use of the TPT in studying specifically CT-related psychophysical responses, McGlone and colleagues assessed the sensory and emotional components of touch (via TPT) in a study that investigated cortical activity (via PET) in response to touch of the forearm or palm (McGlone et al. 2012). The TPT revealed a complex of generally greater emotional responses at the forearm versus palm, consistent with the presence of emotionally relevant CT afferents in the forearm but not the palm side of the hand. However, one must exert caution in asserting that strong emotional responses, as measured using the TPT, unequivocally denote strong CT activity. For example, tactile stimulation of facial sites can lead to a large affective responses (Essick et al. 1999), but this is not necessarily a consequence of the nature and density of the facial innervation; the inherent role of facial touch in terms of its social meaning acts as a confound in this case (Heslin et al. 1983). Further, even if emotionally relevant touch is indeed primarily conveyed by CT afferents, we can clearly make emotional judgments to touch of– and by– the hands. Therefore, responses to the TPT combined with microneurography and brain imaging provide a compelling picture, unavailable from each source of information in isolation.

The TPT has also been used to investigate the sensory and emotional concomitants of delayed onset muscle soreness (DOMS; Nagi and Mahns 2013), although in this specific case the TPT did not garner notably more information than the MPQ which was also used. Interestingly, this work suggested a hitherto unknown role for CT afferents in DOMS.

In summary, in the short time over which the TPT has been available, it has proven useful in allowing a relatively detailed breakdown of the sensory and emotional perception of tactile materials. This type of detail, not available if one were to assess solely pleasantness, has illustrated the complexity of tactile perceptions, and has supported the purported role of CT afferents in conveying affect and the emotional significance of touch.

Questions Remaining for a Touch Lexicon

Regarding the TPT and other lexicons, an important question is how few attributes are needed to fully describe a perceptual experience? If perceptual experience is well described by an *n*-dimensional perceptual structure, one might propose rating attributes that anchor the axis extremes. So, if tactile emotional space has *Pleasure* (or *Comfort*) and *Arousal* as its cardinal axes (Fig. 8.5), then one might rate the attributes *comfort* and *irritation* (as anchors of *Comfort*), and *exciting* and *calming* (as anchors of *Arousal*). This assumes that one can rate intermediate points in the space as simply amounts of the anchors. The emotional space found in deriving the TPT seems quite amenable to this, because there are few intermediate attributes; *Pleasure* is anchored by *comfort*, with few attributes denoting intermediate amount of comfort present.

However, despite the enduring interest in producing orthogonal perceptual spaces, researchers have not tended use such spaces to optimize (minimize) the number of questionnaire attributes in this way. In fact, it is not clear that a reductionist treatment of attributes generalizes. For example, consumer science research suggests that simple ratings of the most basic emotions miss information about the emotional experience of consumer goods (Laros and Steenkamp 2005). That is, attributes may not always be well described as amounts of an anchoring attribute. Regardless, the question of how many attributes are required for any perceptual lexicon remains.

Development of Devices for CT Study

A primary issue with any psychophysics is how to adequately control the parameters of stimulation. For tactile perception, a variety of methods have been developed to enable such control. The most common approach has been to precisely engineer the surface that contacts the skin during testing. This engineering is a fundamental part of common tactile detection and discrimination testing tasks. For example, precision gratings and other shapes of various types have been developed to study tactile spatial acuity (Lederman 1974; Lévêque et al. 2000; Morley et al. 1983; Patel et al. 1997), embossed letters have been reported as useful for the assessment of lingual tactile acuity (Essick et al. 2003), and calibrated filaments (Von Frey hairs/ Semmes-Weinstein monofilaments) are popular in the assessment of light touch (see Jerosch-Herold 2005 for a review of such tasks in a clinical context). Some examples of these are shown in Fig. 8.6. More sophisticated variants on these established devices have been developed recently, such as those which allow vibrotactile

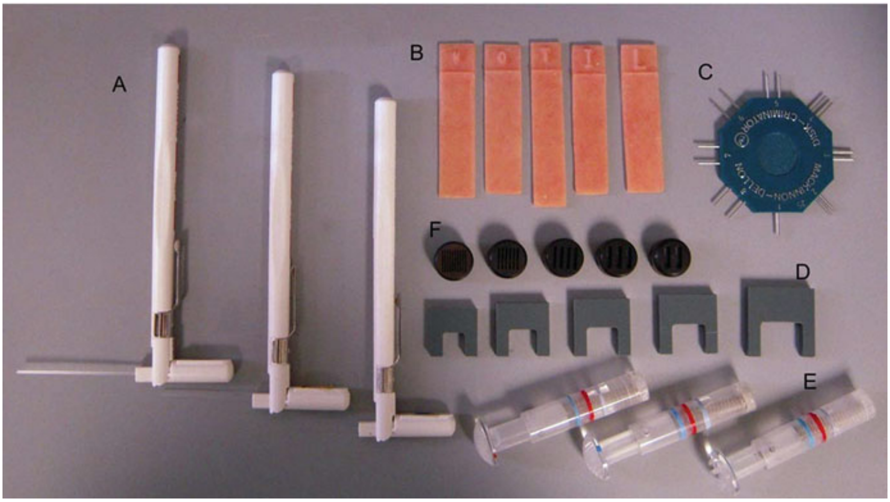


Fig. 8.6 Typical stimuli used to assess the discriminative properties of touch (**a**) VonFrey hairs for light touch detection tasks; (**b**) embossed letters for assessment of lingual tactile acuity; (**c**) two-point discrimination tool (Mackinnon Disk-Criminator); (**d**) gap detection stimuli; (**e**) JVP domes for the assessment of spatial acuity on sensitive skin sites (e.g., fingertip); and (**f**) grating stimuli with a similar purpose to (**e**)

stimuli to be delivered to two nearby skin sites with good, independent control of the two stimulator tips (Tannan et al. 2005).

However, the study of emotional touch requires the control of different and potentially rather more complex stimuli. The tactile emotional impact of an engineered plastic grating is unlikely to be great. In contrast, one of the most obviously emotionally impactful touches is a caress; in more prosaic terms, a stimulus gently brushed across the skin. Therefore, devices to effectively study emotional touch must be able to provide an 'ecologically relevant' brushing stimulus, while allowing for good control of the parameters of the brushing.

Early Approaches to Affective Stimulus Delivery

Early approaches to studying tactile affect did not use good stimulus control, because that type of control was beyond the engineering available to researchers. Commonly, stimulus materials to be assessed have been freely manipulated, such as by rubbing or pinching fabrics between fingers and thumb (Major 1895). These methods have established some of the basics of emotional touch, in terms of what tends to feel pleasant, although such methods are not able to determine how stimulus manipulation alters emotional judgments.

However, even in recent years very approximate stimulus control has been accepted for the study of emotional touch, with hand application of soft cosmetic or artist's brushes being commonly used as a prototypically pleasant stimulus (Cascio et al. 2008; Olausson et al. 2002, 2008b). This is acceptable in the sense that a pleasant stimulus, such as a soft cosmetic brush, remains pleasant almost regardless of how it is moved across the skin, even if it is not delivered with the optimal stimulus parameters. Therefore, if one wishes to simply deliver 'something pleasant,' barely controlled manual brushing is often a pragmatic choice, requiring no sophisticated engineering beyond that available by default in the experimenter's hand.

Automated Stimulus Delivery Control

One of the early attempts to provide improved stimulus control was via a brushing stimulator that allowed different materials to be moved across the skin with controlled velocity (Essick et al. 1999). The development of this robotic device was a primary step in CT-related work, not only to provide hitherto unavailable stimulus control, but also to control for experimenter-induced effects. For example, the physical attractiveness of the experimenter can influence the responses he/she obtains from participants (Donley and Allen 1977; Hartnett et al. 1976), and males and females can respond differently to 'objective' stimuli, contingent on the sex of the experimenter (Levine and De Simone 1991). The pressure exerted against the skin was controlled to a limited extent by mounting stimulus materials on a resilient foam pad, but it was not explicitly characterized. This system allowed the authors to be the first to demonstrate that pleasantness has a curvilinear relationship with stimulus speed, with the greatest pleasantness being perceived for stimuli moved over the skin at c. 5 cm s^{-1} (Fig. 8.7). Additional findings showed that replicate pleasantness ratings were reasonably reliable (intraclass correlation of 0.45), and confirmed that unpleasantness was the inverse of pleasantness.

The basic concept underlying the brushing stimulator was used in subsequently engineering a more sophisticated device, termed the 'Rotary Tactile Stimulator' (RTS). The early construction and programming of the RTS was described by

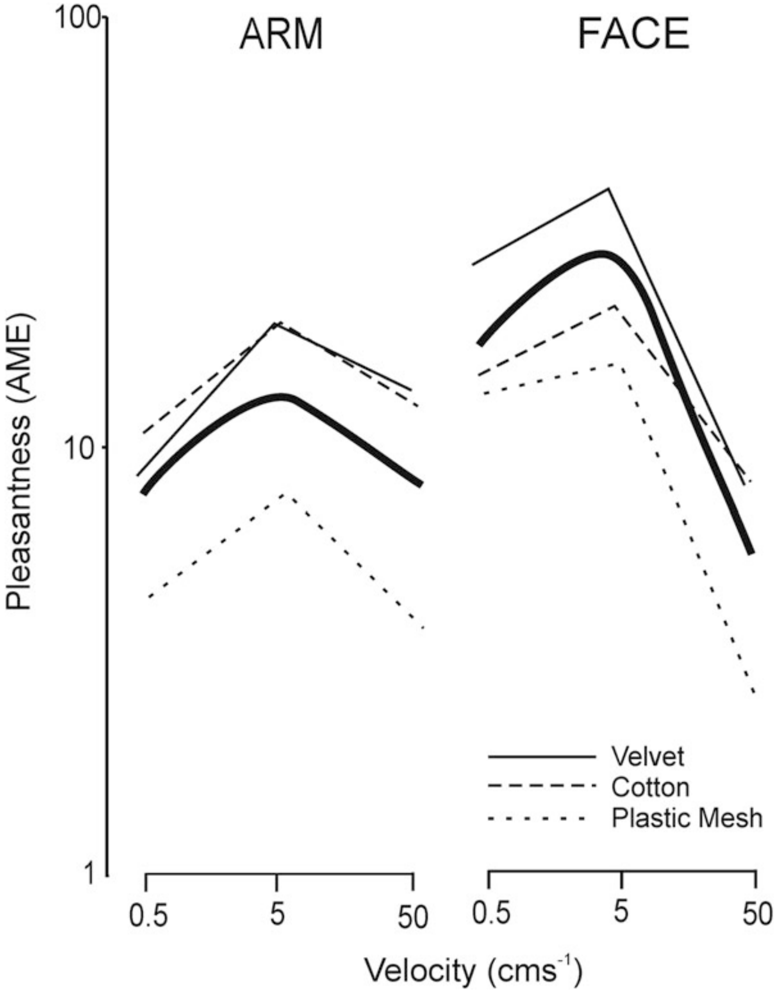


Fig. 8.7 The relationship between pleasantness and the speed a stimulus is moved against the skin is approximately the same regardless of stimulus or body site. Redrawn from Essick et al. (1999)

Fabricant (2000) and Ragin (2002), with the most recent iteration detailed by Essick et al. (2010), although other researchers had used the device to good effect prior to its full description in 2010 (Löken et al. 2006, 2009; McGlone et al. 2007).

The RTS allows stimuli to be brushed onto, across, and then off the skin with control of brushing direction, speed, and force of indentation into the skin, and with continual readings of the forces and torques occurring during delivery (Fig. 8.8). Up to four stimuli can be studied in the same experiment, each mounting on one of four arms. Rotation of the arms is dealt with by a brushless DC motor, reduction drive, and position encoder located in the head of the device. Interposed between the shaft of the DC motor assembly and the hub, is a 6-axis force/torque transducer. The DC motor and transducer assembly is mounted on a linear stepper motor, which allows

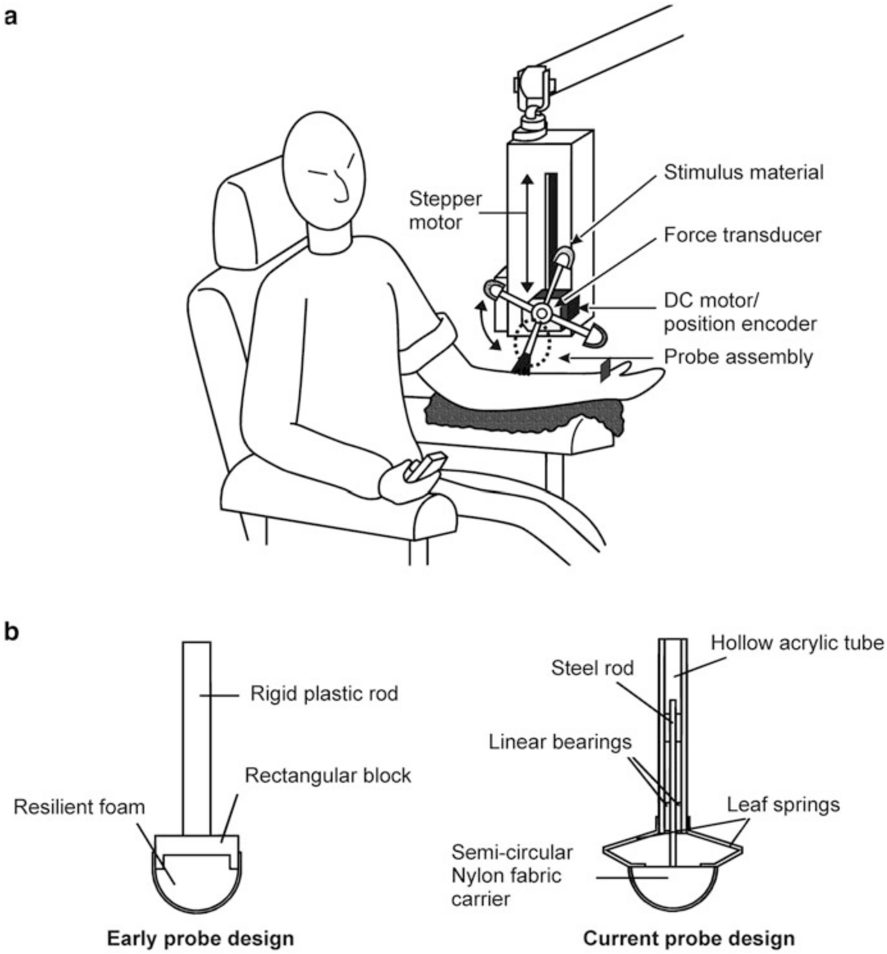


Fig. 8.8 The Rotary Tactile Stimulator (RTS), a device designed to provide highly controlled brushing stimuli to the skin (**a**). Different probe designs are shown in (**b**) and (**c**)

it to move perpendicularly to the skin surface. Both the DC and stepper motors are under computer control.

Any device that interacts with the skin requires calibration. The RTS is no different. The weight of all four probes and the hub contribute to the forces sensed by the transducer, and therefore each probe must be aligned perpendicular to the skin with the static forces and torques recorded and subtracted from all subsequent force and torque measurements. A second calibration stage is needed to enable each textured material to be delivered at a targeted normal force level. In this case, for any given probe and force combination the distance must be determined that the linear drive needs to move toward the skin from its home position to compress the probe and skin sufficiently to achieve the targeted force level. In actual use, the peak normal force level attained when the probe moves across the skin is typically twice the peak force level observed during vertical movement alone. This is primarily due to the different mechanical responses of the skin to tangential versus vertical displacement.

The design of the probes was critical to delivering as accurate and reproducible forces to the skin as possible. Ideally, the head of the probe that carries the stimulus should be compressible in the normal direction, with a reproducible force/distance curve, but should not move at all in the tangential or lateral directions. An early probe design consisted of a rigid plastic rod, at the end of which was a rectangular block, onto which was mounted a block of foamed plastic with a semicircular outer profile (Fig. 8.8b). Side-cheeks of thin plastic held the foam block in place and prevented lateral movement. The stimulus (fabric) sample was stretched over the semicircular outer edge of the foam block. It was recognized that this design suffered from the drawback that at higher forces the foam block was prone to distortion and lateral movement. Also, the repeatability of compression of the foam was unknown. In recognition of these shortcomings, an improved design was produced.

The most recent design is very similar to a motorcycle's front fork suspension: The probe assembly consists of a hollow acrylic tube inside of which are two miniature linear bearings (Fig. 8.8c). A steel rod travels freely in these bearings. At the end of the rod is fixed a rigid semicircular nylon fabric carrier. Two steel V-shaped leaf springs attach the ends of the fabric carrier to the sides of the acrylic tube. The springs provide resistance to compression and also hold the fabric carrier in the direction of rotation. This design is better than the older 'foam block' design in that the actual peak normal force recorded during a sweep for a given set of sweep parameters is quite consistent, and the leaf springs are not subject to losing their mechanical performance, at least for any biologically reasonable force delivery.

The main psychophysical study that has used the RTS was relatively complex, assessing pleasantness responses to multiple fabric materials, at multiple body sites, for both sexes (Essick et al. 2010). Experiments using the two probe designs were reported, although the two probes were used to deliver different combinations of normal force levels and stimulus materials, rendering direct assessment of probe performance difficult. The study primarily illustrated the complex nature of the pleasantness response. The simplest take home message was confirmation of the basic curvilinear nature of the pleasantness response with stimulus speed (viz. Fig. 8.7). A more complex finding was that increasing stimulus normal force decreased pleasantness to a different extent among body sites, with the greatest effect observed on the face, the least on the calf. Although males and females responded in a broadly similar way, differences between the sexes were observed, too. For example, fast, high force stimuli were rated as more pleasant when moved over the male versus female body. The basis of this might have been mechanical, such as in frictional differences attributable to differences in body hair coverage under the moving stimulus, or in social–cognitive effects unrelated to the physical stimulus per se (Hertenstein et al. 2006a, b; Heslin et al. 1983; Koutantji et al. 1998; Lautenbacher and Rollman 1993).

The RTS is eminently suited to any psychophysics that requires highly controlled brushing stimuli. This suitability means that it has been an ideal tool for the study of CT afferent activity with microneurography, for both characterizing the CT-spike firing rates versus velocity tuning curve (Löken et al. 2009) and for delivering stimuli designed to maximize CT afferent activity, if that were desired. It is also possible to use the RTS in rather novel and informative ways, exemplified by Ackerley and colleagues (2012) who used the RTS to move fabric samples soaked to different extents in water to investigate how veridical wetness perception is, and how this type of perception varies over the body.

Recently, a linear tactile stimulator (LTS) has been derived, primarily for use within an MRI environment (Fig. 8.9). The device is in many ways a return to the brushing stimulator noted earlier, albeit with more sophisticated design and engineering. The small size of the LTS and its MRI-compatibility allow for experiments that would be impossible to conduct using the RTS.

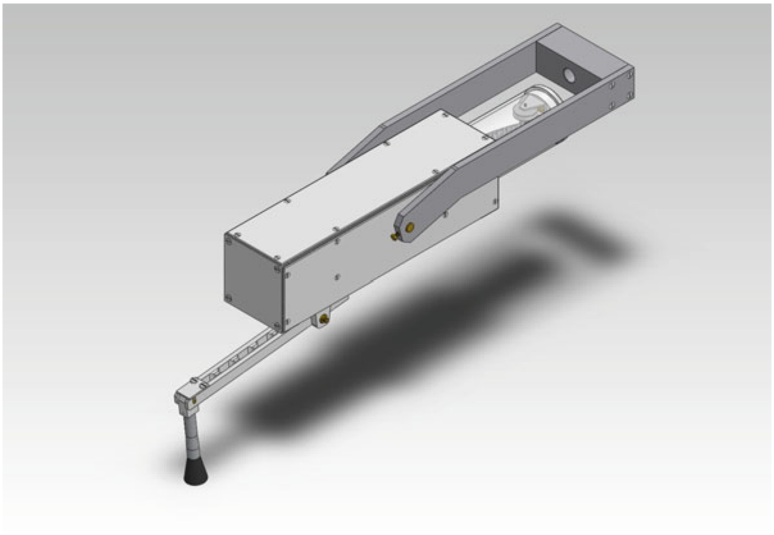


Fig. 8.9 The Linear Tactile Stimulator (LTS), engineered by Dancer Design (UK), of utility in MRI environments

Stimulus Characterization for Free Exploration

The RTS and similar devices take the approach of trying to provide a very precisely controlled, accurate stimulus to the skin. Such an approach forces very rigorous experimental setup, with any participants generally required to stay in a fixed position, often with the assistance of straps, foam pillows, and other restrictive devices. Devices such as the RTS are tailored to deliver stimuli which are passively received by an individual. The RTS is not equipped to address or characterize active manipulations of stimuli by a perceiver. However, passive receipt of a stimulus might not be the best way of assessing affect. Indeed, it is well known that affective attributes of touch are influenced by the nature of the touch well beyond its simple parametric nature; interpersonal touch cannot be truly replicated by simply replicating the speeds and forces that occur during the touch. For example, one tends to assess one's own skin (intrapersonal touch) as feeling less pleasant than the interpersonal touch of someone else's skin (Guest et al. 2009). The basis of this difference could be in the sensory receptors involved in the two types of touch (Von Békésy 1963) or in the social meaning that may be conveyed by interpersonal (but not intrapersonal) touch (Hertenstein et al. 2006a, b). Similarly, it is not possible to tickle oneself (Blakemore et al. 2000; Weiskrantz et al. 1971), probably because information regarding the tickling motions are available to the self during 'attempted self-tickle' but not when tickled 'conventionally,' that is, by someone else (Wolpert 1997). All of these observations show that passive receipt of stimulus is unlikely to provide a complete story of—in particular—emotional touch perception.

A different approach to the study of affective touch is to provide limited stimulus control, but to characterize the forces that occur at the skin site during stimulation. This approach allows the active explorations of a perceiver to be characterized and has the potential to allow more ecologically relevant touch to be investigated. For example, we know that CT afferent activity tends to be greatest for received touches that stroke the skin at circa 5 cm s^{-1} (Essick et al. 1999; Löken et al. 2009). However, we do not know whether individuals naturally choose to assess materials using this speed of touch. If someone is to assess the pleasantness of a piece of velvet, do they tend to gravitate toward stroking at 5 cm s^{-1}? Although this is the speed one would expect if the observer aimed to maximize CT afferent activity, there are no such afferents known in the finger. Therefore, there is no clear neural reason why the preferred touch speed should be the same for active touch by the finger and touch received by hairy body sites. Thus, as well as active touch being of interest and ecological importance in its own right, it also allows one to compare the responses of CT-innervated and CT-void body sites.

To this end, several devices have been reported that allow the frictional and other forces that occur during naturalistic touch of a surface to be recorded (Gee et al. 2005; Guest et al. 2012a; Skedung et al. 2010; Smith et al. 2002a). All in essence consist of a rigid plate which is coupled to sensitive force transducers. Figure 8.10 shows the 'force plate' used in our work, which is based on the type of force transducer used in the RTS. In use, each device is potentially very simple: as something

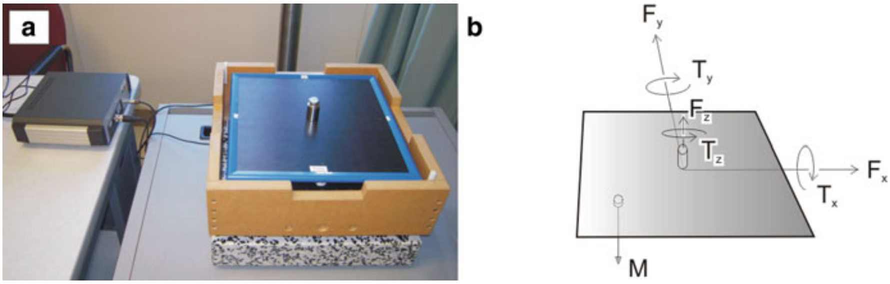


Fig. 8.10 A 'force plate' device, suited for collecting mechanical event data during active touch. Forces along, and torques around three axes are recorded, along with vibrotactile information (M)

on the force plate surface is touched, a continual reading of the forces and torques applied to the plate is obtained. So, an observer could be asked to freely assess something on the force plate, with the plate showing what actually happened at the fingertip during the assessment, in terms of finger movements and the forces and torques generated between the moving finger and the surface. The forces and torques can be used to derive further quantities of interest, such as the coefficient of dynamic friction at any point during the time course of the touch exploration. We have used the phrase 'Mechanical Events' (MEs) to refer to the various forces, torques, and derived quantities that might be considered.

Although these devices are not specifically for the study of affective touch, they are clearly well suited to the task. For example, the friction measurement system described by Gee et al. (2005) was proposed as a good way to "…provide information so that attractive, desirable products can be designed." One way this might happen is to allow consumers to assess a surface (textile or perhaps a skin analog coated with a cosmetic cream) and then attempt to link subjective ratings of the surface to the concurrent recordings of surface friction or other relevant measures.

In reality, entirely free exploration of a surface is problematic in that it could provide a relatively sparse data set if explorations were but fleeting. Indeed, no studies are available to date that consider entirely free assessment of surfaces while recording the mechanical events that occur. A partial exception to this are studies conducted by Smith and colleagues that looked at the strategies used during tactile search for a small asperity on the force plate surface (Smith et al. 2002b), and at the role of friction and forces at the fingertip in assessing roughness (Smith et al. 2002a). However, the former study did not investigate links between perception and mechanical events. The latter study investigated such links, and of all comparable studies, is probably the one that has allowed participants the most freedom in terms of their behavior. The restriction placed on participants was that each person could make a single, unidirectional traverse over a stimulus surface of fixed length; however, their chosen stroking speed and force were unconstrained.

A pragmatic compromise we have taken in our most recent experiments is for participants to continually explore a surface but use every ecologically relevant touch speed and force (Guest et al. 2012a; Hopkinson et al. 2008). In practice, this involves providing continual feedback to the participant as they explore a surface, in terms of what speed and force they should use, and how well they are managing to achieve the target speeds and forces.

This approach has enabled some links to be found between the sensory perception of a surface and the nature of the stimulus at the fingertip, but has been less successful in linking affective judgments to the physical stimulus. For example, fluids that feel more viscous when explored on a skin-like surface tend to be those that have (perhaps unsurprisingly) greater friction (Guest et al. 2012a). However, we have found no such links between emotional attributes such as pleasantness or sensuality and the physical nature of the stimulus. This negative finding could be due to the lack of a strong emotional response for the active assessment of inanimate materials, as opposed to the active assessment of one's own or another's body (Guest et al. 2009, 2014). A second possibility is that the 'exhaustive exploration' paradigm is too far divorced from naturalistic touch to provide a strong emotional impetus. Yet, another possibility is that the analysis methods used for these complex datasets have not been optimized. It is also true that we have used the force plate only to assess lubricated surfaces and it may be that these surfaces are especially difficult to study. For example, different lubrication regimes allow any underlying surface texture to influence perception to differing extents, with regimes potentially changing within a single touch episode (see Guest et al. 2013 for a review). Finally, one should keep in mind that the lack of CT-innervation for the fingertip might underlie some of these weak emotional responses.

Conclusions

Methods and devices for the study of emotional touch have developed considerably since the inception of the field. These developments have included both what perceptual attributes should be studied, and how to best deliver stimuli to be rated in terms of their emotional content.

In terms of lexicons for touch, we have arrived at a tool—the TPT—that allows for principled and successful study of the sensory and emotional components of touch. Refinement of this tool is still desirable, if at all possible; empirically, for any given stimulus, typically few of the 40 attributes of the TPT are considered to be applicable. Unfortunately, it is not clear a priori as to what attributes will not apply to a given stimulus, especially any stimuli that are hitherto unexplored. As such it is unclear how streamlined the TPT might become. It is even possible that multiple TPT variants will exist, tailored for different gross classes of stimuli. Indeed, we have traveled this path to a limited extent by swapping in and out a limited set of attributes when studying the perception of lubricated surfaces (Guest et al. 2012a, b).

In terms of devices, one major challenge for the field is reconciling the technical and data complexity of studying naturalistic touch. It is clear that we can obtain 'good' psychophysical data from highly controlled, passively received stimuli—and for electrophysiological studies this will probably remain a necessary gold standard.

Otherwise, there is a need to be able to characterize what people actually do, and what mechanical stimulus consequently occurs, when making tactile judgments, especially those with an affective component. It is technically feasible to record mechanical event data from the naturalistic assessment of a subset of stimuli (e.g., anything that can be explored over a hard, planar surface). However, how to deal with the complex data that arise is a work in progress.

References

Ackerley R, Olausson H, Wessberg J, McGlone FP (2012) Wetness perception across body sites. Neurosci Lett 522:73–77

Almeida IF, Gaio AR, Bahia MF (2008) Skinfeel analysis of oleogels. J Sens Stud 23:92–113

Bergmann Tiest WM, Kappers AMI (2006) Analysis of haptic perception of materials by multidimensional scaling and physical measurements of roughness and compressibility. Acta Psychol (Amst) 121:1–20

Bhushan N, Rao AR, Lohse GL (1997) The texture lexicon: understanding the categorization of visual texture terms and their relationship to texture images. Cognit Sci 21(2):219–246

Björnsdotter M, Larsson L, Ljungberg T (2000) Post-conflict affiliation in two captive groups of black-and-white Guereza Colobus Guereza. Ethology 106:289–300

Blakemore S-J, Wolpert D, Frith C (2000) Why can't you tickle yourself? Neuroreport 11:R11–R16

Cardello AV, Winterhalter C, Schutz HG (2003) Predicting the handle and comfort of military clothing fabrics from sensory and instrumental data: development and application of new psychophysical methods. Text Res J 73:221–237

Cascio CJ, McGlone FP, Folger S, Tannan V, Baranek G, Pelphrey KA et al (2008) Tactile perception in adults with autism: a multidimensional psychophysical study. J Autism Dev Disord 38:127–137

Diamond A, Amso D (2008) Contributions of neuroscience to our understanding of cognitive development. Curr Dir Psychol Sci 17:136–141

Donley B, Allen B (1977) Influences of experimenter attractiveness and ego-involvement on paired-associates learning. J Soc Psychol 101:151–152

Dravnieks A (1982) Odor quality: semantically generated multidimensional profiles are stable. Science 218(4574):799–801

Dravnieks A (1985) Atlas of odor character profiles (no. (PCN) 05-061000-36). ASTM, Philadelphia

Essick GK, Chopra A, Guest S, McGlone FP (2003) Lingual tactile acuity, taste perception, and the density and diameter of fungiform papillae in female subjects. Physiol Behav 80:289–302

Essick GK, James A, McGlone FP (1999) Psychophysical assessment of the affective components of non-painful touch. Neuroreport 10:2083–2087

Essick GK, McGlone FP, Dancer C, Fabricant D, Ragin Y, Phillips N et al (2010) Quantitative assessment of pleasant touch. Neurosci Biobehav Rev 34:192–203

Fabricant D (2000) A new stimulator for studying the affective components of touch. Unpublished Master's thesis, University of North Carolina at Chapel Hill, Chapel Hill

Foxall G, Greenley G (1998) The affective structure of consumer situations. Environ Behav 30(6):781–798

Gee MG, Tomlins P, Calver A, Darling RH, Rides M (2005) A new friction measurement system for the frictional component of touch. Wear 259:1437–1442

Guest S, Dessirier JM, Mehrabyan A, McGlone FP, Essick GK, Gescheider GA et al (2011) The development and validation of sensory and emotional scales of touch perception. Atten Percept Psychophys 73:531–550

Guest S, Essick G, Mehrabyan A, Dessirier JM, McGlone FP (2014) Effect of hydration on the tactile and thermal sensitivity of the lip. Physiol Behav 123:127–135
Guest S, Essick GK, Dessirier JM, Blot K, Lopetcharat K, McGlone FP (2009) Sensory and affective judgments of skin during inter- and intrapersonal touch. Acta Psychol (Amst) 130:115–126
Guest S, McGlone FP, Hopkinson A, Schendel ZA, Blot K, Essick G (2013) Perceptual and sensory-function consequences of skin care products. J Cosmet Dermatol Sci Appl 3:66–78
Guest S, Mehrabyan A, Essick G, Phillips N, Hopkinson A, McGlone FP (2012a) Physics and tactile perception of fluid-covered surfaces. J Text Stud 43:77–93
Guest S, Mehrabyan A, Essick GK, McGlone FP, Hopkinson A (2012b) Perception of fluids with diverse rheology applied to the axillary versus volar forearm skin. Somatosens Motor Res 29:89–102
Harlow HF (1958) The nature of love. Am Psychol 13:673–685
Harper R, Bate-Smith EC, Land DG (1968) Odour description and odour classification. Churchill, London
Hartnett JJ, Gottlieb J, Hayes RL (1976) Social facilitation theory and experimenter attractiveness. J Soc Psychol 99:293–294
Hertenstein MJ, Keltner D, App B, Bulleit BA, Jaskolka AR (2006a) Touch communicates distinct emotions. Emotion 6:528–533
Hertenstein MJ, Verkamp JM, Kerestes AM, Holmes RM (2006b) The communicative functions of touch in humans, nonhuman primates, and rats: a review and synthesis of the empirical research. Genet Soc Gen Psychol Monogr 132:5–94
Heslin R, Nguyen TD, Nguyen ML (1983) Meaning of touch: the case of touch from a stranger or same sex person. J Nonverbal Behav 73:147–157
Holbrook MB, Batra R (1987) Assessing the role of emotions as mediators of consumer responses to advertising. J Consum Res 14(3):404–420
Hollins M, Bensmaïa S, Karlof K, Young F (2000) Individual differences in perceptual space for tactile textures: evidence from multidimensional scaling. Percept Psychophys 62(8):1534–1544
Hollins M, Faldowski R, Rao S, Young F (1993) Perceptual dimensions of tactile surface texture: a multidimensional scaling analysis. Percept Psychophys 54(6):697–705
Hopkinson A, Essick G, Mehrabyan A, Guest S, Lawton G, Williams AKNW et al (2008). The role of friction in the tactile perception of lubricated surfaces. Paper presented at the Materials & Sensations
Jerosch-Herold C (2005) Assessment of sensibility after nerve injury and repair: a systematic review of evidence for validity, reliability and responsiveness of tests. J Hand Surg Br 30(3):252–264
King SC, Meiselman HL (2010) Development of a method to measure consumer emotions associated with foods. Food Qual Prefer 21:168–177
Koutantji M, Pearce SA, Oakley DA (1998) The relationship between gender and family history of pain with current pain experience and awareness of pain in others. Pain 77:25–31
Laros FJM, Steenkamp J-BEM (2005) Emotions in consumer behavior: a hierarchical approach. J Bus Res 58:1437–1445
Lautenbacher S, Rollman GB (1993) Sex differences in responsiveness to painful and non-painful stimuli are dependent upon the stimulation method. Pain 53:255–264
Lederman SJ (1974) Tactile roughness of grooved surfaces: the touching process and effects of macro- and microsurface structure. Percept Psychophys 16(2):385–395
Lederman SJ, Klatzky RL (1987) Hand movements: a window into haptic object recognition. Cogn Psychol 19:342–368
Lederman SJ, Klatzky RL (1990) Haptic classification of common objects: knowledge-driven exploration. Cogn Psychol 22:421–459
Lévêque J-L, Dresler J, Ribot-Ciscar E, Roll J-P, Poelman C (2000) Changes in tactile spatial discrimination and cutaneous coding properties by skin hydration in the elderly. J Invest Dermatol 115:454–458

Levine FM, De Simone LL (1991) The effects of experimenter gender on pain report in male and female subjects. Pain 44:69–72
Löken LS, Evert M, Wessberg J (2012) Pleasantness of touch in human glabrous and hairy skin: order effects on affective ratings. Brain Res 1417:9–15
Löken LS, Wessberg J, McGlone FP, Olausson H (2006) The response of human unmyelinated afferents to brush stroking with varying velocity. Society for neuroscience—abstracts poster 143.5
Löken LS, Wessberg J, Morrison I, McGlone FP, Olausson H (2009) Coding of pleasant touch by unmyelinated afferents in humans. Nat Neurosci 12(5):547–548
Major DR (1895) On the affective tone of simple sense-impressions. Am J Psychol 7:57–77
Manzocco L, Rumignani A, Lagazio C (2013) Emotional response to fruit salads with different visual quality. Food Qual Prefer 28:17–22
McGlone FP, Olausson H, Boyle JA, Jones-Gotman M, Dancer C, Guest S et al (2012) Differences in pleasant touch processing between glabrous and hairy skin in humans. Eur J Neurosci 35:1782–1788
McGlone FP, Vallbo Å, Olausson H, Loken L, Wessberg J (2007) Discriminative touch and emotional touch. Can J Exp Psychol 61:175–183
McGlone FP, Wessberg J, Olausson H (2014) Discriminative and affective touch: sensing and feeling. Neuron 82:737–755
McNair DM, Lorr M, Droppleman LF (1971) Profile of mood states. Educational and Industrial Testing Service, San Diego
Meaney MJ, Mitchell JB, Aitken DH, Bhatnagar S, Bodnoff SR, Iny LJ et al (1991) The effects of neonatal handling on the development of the adrenocortical response to stress: implications for neuropathology and cognitive deficits in later life. Psychoneuroendocrinology 16(1–3):85–103
Meerlo P, Horvath KM, Nagy GM, Bohus B, Koolhaas JM (1999) The influence of postnatal handling on adult neuroendocrine and behavioural stress reactivity. J Neuroendocrinol 11:925–933
Mehrabian A (1970) A semantic space for nonverbal behavior. J Consult Clin Psychol 35(2):248–257
Melzack R (1975) The McGill pain questionnaire: major properties and scoring methods. Pain 1:277–288
Melzack R (1987) The short-form McGill Pain Questionnaire. Pain 30:191–197
Melzack R, Torgerson WS (1971) On the language of pain. Anesthesiology 34(1):50–59
Montagu A (1986) Touching: the human significance of the skin, 3rd edn. Harper & Row, New York
Morley JW, Goodwin AW, Darian-Smith I (1983) Tactile discrimination of gratings. Exp Brain Res 49:291–299
Na Y, Kim C (2001) Quantifying the handle and sensibility of woven silk fabrics. Text Res J 71:739–742
Nagi SS, Mahns DA (2013) C-tactile fibers contribute to cutaneous allodynia after eccentric exercise. J Pain 14(5):538–548
Okamoto S, Nagano H, Yamada Y (2013) Psychophysical dimensions of tactile perception of textures. IEEE Trans Haptics 6(1):81–93
Olausson H, Cole J, Rylander K, McGlone FP, Lamarre Y, Wallin BG et al (2008a) Functional role of unmyelinated tactile afferents in human hairy skin: sympathetic response and perceptual localization. Exp Brain Res 184:135–140
Olausson H, Cole J, Vallbo Å, McGlone FP, Elam M, Krämer H et al (2008b) Unmyelinated tactile afferents have opposite effects on insular and somatosensory cortical processing. Neurosci Lett 436:128–132
Olausson H, Lamarre Y, Backlund H, Morin C, Wallin BG, Starck G et al (2002) Unmyelinated tactile afferents signal touch and project to insular cortex. Nat Neurosci 5:900–904
Osgood CE (1952) The nature and measurement of meaning. Psychol Bull 49(3):197–237
Osgood CE (1966) Dimensionality of the semantic space for communication via facial expressions. Scand J Psychol 7:1–30
Osgood CE, Suci GJ (1955) Factor analysis of meaning. J Exp Psychol 50(5):325–338

Patel J, Essick GK, Kelly DG (1997) Utility of square-wave gratings to assess perioral spatial acuity. J Oral Maxillofac Surg 55:593–601

Picard D, Dacremont C, Valentin D, Giboreau A (2003) Perceptual dimensions of tactile textures. Acta Psychol (Amst) 114:165–184

Ragin Y (2002) Development and testing of a psychophysical protocol for studies on the affective components of touch. Unpublished Masters dissertation, University of North Carolina at Chapel Hill, Chapel Hill

Ripin R, Lazarsfeld PF (1937) The tactile-kinaesthetic perception of fabrics with emphasis on their relative pleasantness. J Appl Psychol 21:198–224

Russell JA, Mehrabian A (1977) Evidence for a three-factor theory of emotions. J Res Pers 11:273–294

Russell JA, Steiger JH (1982) The structure in persons' implicit taxonomy of emotions. J Res Pers 16:447–469

Skedung L, Danerlöv K, Olofsson U, Aikala M, Niemi K, Kettle J et al (2010) Finger friction measurements on coated and uncoated printing papers. Tribol Lett 37:389–399

Smith AM, Chapman CE, Deslandes M, Langlais J-S, Thibodeau M-P (2002a) Role of friction and tangential force variation in the subjective scaling of tactile roughness. Exp Brain Res 144:211–223

Smith AM, Gosselin G, Houde B (2002b) Deployment of fingertip forces in tactile exploration. Exp Brain Res 147:209–218

Spence C, Gallace A (2011) Multisensory design: reaching out to touch the consumer. Psychol Mark 28(3):267–308

Stevenson RJ, Boakes RA (2003) A mnemonic theory of odor perception. Psychol Rev 110:340–364

Tannan V, Dennis R, Tommerdahl M (2005) A novel device for delivering two-site vibrotactile stimuli to the skin. J Neurosci Methods 147:75–81

Von Békésy G (1963) Interaction of paired sensory stimuli and conduction in peripheral nerves. J Appl Physiol 18:1276–1284

Weiskrantz L, Elliot J, Darlington C (1971) Preliminary observations on tickling oneself. Nature 230:598–599

Wolpert D (1997) Computational approaches to motor control. Trends Cogn Sci 1:209–216