Kitada, R., Johnsrude, I., Kochiyama, T. & **Lederman, S.J** (2010). ***Brain networks involved in haptic and visual identification of facial expressions of emotion: An fMRI study.*** Neuroimage, 49(2), 1677-1689.

Abstract
Previous neurophysiological and neuroimaging studies have shown that a cortical network involving the inferior frontal gyrus (IFG), inferior parietal lobe (IPL) and cortical areas in and around the posterior superior temporal sulcus (pSTS) region is employed in action understanding by vision and audition. However, the brain regions that are involved in action understanding by touch are unknown. Lederman et al. (2007) recently demonstrated that humans can haptically recognize facial expressions of emotion (FEE) surprisingly well. Here, we report a functional magnetic resonance imaging (fMRI) study in which we test the hypothesis that the IFG, IPL and pSTS regions are involved in haptic, as well as visual, FEE identification. Twenty subjects haptically or visually identified facemasks with three different FEEs (disgust, neutral and happiness) and casts of shoes (shoes) of three different types. The left posterior middle temporal gyrus, IPL, IFG and bilateral precentral gyrus were activated by FEE identification relative to that of shoes, regardless of sensory modality. By contrast, an inferomedial part of the left superior parietal lobule was activated by haptic, but not visual, FEE identification. Other brain regions, including the lingual gyrus and superior frontal gyrus, were activated by visual identification of FEEs, relative to haptic identification of FEEs. These results suggest that haptic and visual FEE identification rely on distinct but overlapping neural substrates including the IFG, IPL and pSTS region.

Lederman, S.J., Kitada, R., & Klatzky, R.L. (2010). ***Haptic Face Processing and its Relation to Vision.*** In M.J. Naumer & J. Kaiser (eds). Multisensory Object Perception in the Primate Brain. Springer Verlag, Ch 15, pp. 273-300

Abstract
In this chapter, we address the nature of haptic face perception. People can perform this task well above chance with relatively little training. We concentrate on how the haptic system processes and represents facial identity and emotional expressions both functionally and neurally. With respect to face processes, we consider issues that pertain to configural versus feature-based processing, to visual-mediation versus multisensory processing, and to intersensory transfer. With respect to face representations, we consider the role of orientation, the relative importance of different facial regions to haptic face perception, and the theoretical approaches that have been applied to the study of human facial emotions. Additionally, we address what is known about the corresponding neural mechanisms that subserve haptic face perception. We also relate this relatively new sub-area of haptic perception to the more extensive literature on visual face processing.

Kitada, R., Johnsrude, I., Kochiyama, T. & **Lederman, S.J.** (2009). ***Functional specialization and convergence in the occipitotemporal cortex supporting haptic and visual identification of human faces and body parts: An fMRI study.*** Journal of Cognitive Neuroscience, 21(10), 2027-2045

Abstract
Humans can recognize common objects by touch extremely well whenever vision is unavailable. Despite its importance to a thorough understanding of human object recognition, the neuroscientific study of this topic has been relatively neglected. To date, the few published studies have addressed the haptic recognition of nonbiological objects. We now focus on haptic recognition of the human body, a particularly salient object

category for touch. Neuroimaging studies demonstrate that regions of the occipito-temporal cortex are specialized for visual perception of faces (fusiform face area, FFA) and other body parts (extrastriate body area, EBA). Are the same category-sensitive regions activated when these components of the body are recognized haptically? Here, we use fMRI to compare brain organization for haptic and visual recognition of human body parts. Sixteen subjects identified exemplars of faces, hands, feet, and nonbiological control objects using vision and haptics separately. We identified two discrete regions within the fusiform gyrus (FFA and the haptic face region) that were each sensitive to both haptically and visually presented faces; however, these two regions differed significantly in their response patterns. Similarly, two regions within the lateral occipito-temporal area (EBA and the haptic body region) were each sensitive to body parts in both modalities, although the response patterns differed. Thus, although the fusiform gyrus and the lateral occipito-temporal cortex appear to exhibitmodality-independent, category-sensitive activity, our results also indicate a degree of functional specialization related to sensory modality within these structures.

Lederman, S.J., Klatzky, R.L., Rennert-May, E., Lee, J.H., Ng, K., & Hamilton, C. (2008). ***Haptic processing of facial expressions of emotion in 2D raised-line drawings.*** IEEE Transactions on Haptics, 1(1), 27-38

Abstract
Participants haptically (versus visually) classified universal facial expressions of emotion (FEEs) depicted in simple 2D raised-line displays. Experiments 1 and 2 established that haptic classification was well above chance; face-inversion effects further indicated that the upright orientation was privileged. Experiment 2 added a third condition in which the normal configuration of the upright features was spatially scrambled. Results confirmed that configural processing played a critical role, since upright FEEs were classified more accurately and confidently than either scrambled or inverted FEEs, which did not differ. Because accuracy in both scrambled and inverted conditions was above chance, feature processing also played a role, as confirmed by commonalities across confusions for upright, inverted, and scrambled faces. Experiment 3 required participants to visually and haptically assign emotional valence (positive/negative) and magnitude to upright and inverted 2D FEE displays. While emotional magnitude could be assigned using either modality, haptic presentation led to more variable valence judgments. We also documented a new face-inversion effect for emotional valence visually, but not haptically. These results suggest that emotions can be interpreted from 2D displays presented haptically as well as visually; however, emotional impact is judged more reliably by vision than by touch. Potential applications of this work are also considered.

Lederman, S.J., Klatzky, R.L., Abramowicz, A., Salsman, K., Kitada, R., & Hamilton, C. (2007). ***Haptic recognition of static and dynamic expressions of emotion in the live face.*** Psychological Science, 18(2), 158-164.

Abstract
If humans can detect the wealth of tactile and haptic information potentially available in live facial expressions of emotion (FEEs), they should be capable of haptically recognizing the six universal expressions of emotion (anger, disgust, fear, happiness, sadness, and surprise) at levels well above chance.We tested this hypothesis in the experiments reported here. With minimal training, subjects’ overall mean accuracy was 51% for static FEEs (Experiment 1) and 74% for dynamic FEEs (Experiment 2). All FEEs except static fear were successfully recognized above the chance level of 16.7%. Complementing these findings, overall confidence and information transmission were higher for dynamic than for corresponding static faces. Our performance

measures (accuracy and confidence ratings, plus response latency in Experiment 2 only) confirmed that happiness, sadness, and surprise were all highly recognizable, and anger, disgust, and fear less so.

Lederman, S.J., Kilgour, A., Kitada, R., Klatzky, R.L. & Hamilton, C. (2007). ***Haptic face processing.*** Canadian Journal of Experimental Psychology, 61(3), 230-241.

Abstract
We present an overview of a new multidisciplinary research program that focuses on haptic processing of human facial identity and facial expressions of emotion. A series of perceptual and neuroscience experiments with live faces and/or rigid three-dimensional facemasks is outlined. To date, several converging methodologies have been adopted: behavioural experimental studies with neurologically intact participants, neuropsychological behavioural research with prosopagnosic individuals, and neuroimaging studies using fMRI techniques. In each case, we have asked what would happen if the hands were substituted for the eyes. We confirm that humans can haptically determine both identity and facial expressions of emotion in facial displays at levels well above chance. Clearly, face processing is a bimodal phenomenon. The processes and representationsthat underlie such patterns of behaviour are also considered.

Kilgour, A.R., de Gelder, B., & **Lederman, S.J.** (2004). ***Haptic face recognition and prosopagnosia.*** Neuropsychologia, 42, 707-712.

Abstract

Cases of cross-modal influence have been observed since the beginning of psychological science. Yet some abilities like face recognition are traditionally only investigated in the visual domain. People with normal visual face-recognition capacities identify inverted faces more poorly than upright faces. An abnormal pattern of performance with inverted faces by prosopagnosic individuals is characteristically interpreted as evidence for a deficit in configural processing essential for normal face recognition. We investigated whether such problems are unique to vision by examining face processing by hand in a prosopagnosic individual. We used the haptic equivalent of the visual-inversion paradigm to investigate haptic face recognition. If face processing is specific to vision, our participant should not show difficulty processing faces haptically and should perform with the same ease as normal controls. Instead, we show that a prosopagnosic individual cannot haptically recognize faces. Moreover, he shows similar abnormal inversion effects by hand and eye. These results suggest that face-processing deficits can be found across different input modalities. Our findings also extend the notion of configural processing to haptic face and object recognition.

Kilgour, A., Servos, P., James, T. & **Lederman, S.J.** (2004). ***Haptic face recognition: an fMRI study.*** Brain and Cognition, 54(2), 159-161.

Abstract
We used functional MRI to investigate haptic face recognition and to investigate whether neural pathways dedicated to visual face recognition are also activated when participants explored clay facemasks haptically. Participants were trained to recognize masks of human faces and clay nonsense objects by touch only. During scanning, trained participants were required to identify the facemasks by name and the nonsense objects (nonface controls) by letter. Haptic face recognition produced activation within several extrastriate areas known to be involved in visual face recognition tasks. The results indicate that haptic and visual face recognition activates similar pathways, suggesting that face recognition is a multisensory phenomenon.

Kilgour, A.R., & **Lederman, S.J.** (2002). ***Face recognition by hand.*** Perception & Psychophysics, 64(3) , 339-352.

Abstract
We investigated participants' ability to identify and represent faces by hand. In Experiment 1, participants proved surprisingly capable of identifying unfamiliar live human faces using only their sense of touch. To evaluate the contribution of geometric and material information more directly, we biased participants toward encoding faces more in terms of geometric than material properties, by varying the exploration condition. When participants explored the faces both visually and tactually, identification accuracy did not improve relative to touch alone. When participants explored masks of the faces, thereby eliminating material cues, matching accuracy declined substantially relative to tactual identification of live faces. In Experiment 2, we explored intersensory transfer of face information between vision and touch. The findings are discussed in terms of their relevance to haptic object processing and to the face-processing literature in general.