The Effect of Training on Haptic Classification of Facial Expressions of Emotion in 2D Displays by Sighted and Blind Observers

By

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Abstract

The current study evaluated the effects of training on the haptic classification of culturally universal facial expressions of emotion as depicted in simple 2D raised-line drawings. Blindfolded sighted (N = 60) and blind (N = 4) participants participated in Experiments 1 and 3, respectively. A small vision control study (N = 12) was also conducted (Experiment 2) to compare haptic versus visual learning patterns. A hybrid learning paradigm consisting of pre/post- and old/new-training procedures was used to address the nature of the underlying learning process in terms of token-specific learning and/or generalization. During the Pre-Training phase, participants were tested on their ability to classify facial expressions of emotion using the set with which they would be subsequently trained. During the Post-Training phase, they were tested with the training set (Old) intermixed with a completely novel set (New). For sighted observers, visual classification was more accurate than haptic classification; in addition, two of the three adventitiously blind individuals tended to be at least as accurate as the sighted haptic group. All three groups showed similar learning patterns across the learning stages of the experiment: accuracy improved substantially with training; however, while classification accuracy for the Old set remained high during the Post-Training test stage, learning effects for novel (New) drawings were reduced, if present at all. These results imply that learning by the sighted was largely token-specific for both haptic and visual classification. Additional results from a limited number of blind subjects tentatively suggest that the accuracy with which facial expressions of emotion are classified is not impaired when visual loss occurs later in life.

Co-Authorship

I would like to acknowledge Dr. Susan Lederman's and Dr. Roberta Klatzky's contribution to the conception and design of my project. I performed all of the preliminary experimental set-up, as well as the data collection and processing myself. While analyzing my data, I found Cheryl Hamilton's help indispensable. I also sometimes consulted both her and Dr. Lederman when interpreting my results. I wrote the first and all subsequent drafts of this manuscript, incorporating suggestions and editorial comments made by Dr. Lederman.

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Chapter 1.0 Introduction

Lederman, Klatzky, Rennert-May, Lee and Hamilton (2008) demonstrated that following a short practice period, sighted, blindfolded participants were able to classify upright facial expressions of emotion depicted in 2D raised-lined drawings with 57% accuracy (chance = 17%). The current study was designed to develop this finding further by now formally assessing the effect of training on classification performance in sighted and blind individuals. This study constitutes part of a broader research program in the Touch Lab at Queen's University that focuses on haptic face processing.

Before introducing the present study, we begin with a brief overview of several contextually relevant topics. In Section 2.0, several fundamental aspects of haptic object perception are considered by addressing the following pertinent questions: 1) What are the major constraints imposed on haptic processing? (Section 2.1); 2) Are some object properties more salient than others? (Section 2.2); 3) What does the inherent nature of haptic processing of objects and their properties imply about the use of 2D stimuli in haptics research? (Section 2.3). Section 3.0 reviews research that pertains to the relatively recent finding that faces can be processed haptically: it begins with a brief discussion of haptic classification of facial identity (Section 3.1.1), and concludes with the focus of this thesis, namely, the haptic classification of facial expressions of emotion (Section 3.2.2).

Chapter 2.0 The haptic system: Some fundamental aspects of haptic object processing

The haptic system is a perceptual modality that incorporates afferent signals from both cutaneous and kinesthetic receptors (Loomis & Lederman, 1986). Haptic sensations are encoded by receptors distributed throughout the body, but only those associated with hand function are considered here (for a more comprehensive review, the reader is referred to Jones & Lederman, 2006). Cutaneous information from the glabrous (hairless) volar skin on the hand is coded by four populations of mechanoreceptors: slowly-adapting type I (SA I), slowly-adapting type II (SA II), fast-adapting type I (FA I), and fast-adapting type II (FA II). These receptors differ in their relative speed of adaptation (fast vs. slow), and in the size of their receptive fields (large vs. small). The hairy skin on the back portion of the hand also contains large myelinated mechanoreceptors which have response characteristics that are similar to those found in palmar skin (Greenspan & Bolanowski, 1996). In addition, two types of thermoreceptors, warm and cold, code innocuous sensations of skin temperature. Kinesthetic information about finger position and movement is coded by mechanoreceptors in the muscles, joints, and tendons (Loomis & Lederman, 1986); cutaneous inputs also contribute to hand kinesthesis via activation of SA II units when skin is stretched during finger flexion. The haptic system uses this wealth of cutaneous and kinesthetic information to discriminate, perceive and identify objects in the external world.

How are object properties apprehended by the haptic system? It is helpful to approach this question by considering the limitations inherent in processes associated with manual object exploration.

2.1 What are the major constraints on haptic processing?

Several factors constrain haptic object perception; these determine how object properties are extracted, and ultimately, why certain properties are more salient than others. The following sections address limitations imposed by three important characteristics of haptic processing, namely: a) limited spatial and temporal tactile acuity, b) the relatively small size of the tactile receptive field of view, and b) the need to explore objects using specialized, goal-directed sequential hand movements.

2.1.1 Limited spatial and temporal tactile acuity

Haptic processing is inherently constrained by its ability to resolve spatial and temporal detail. Spatial acuity is often measured using two-point touch threshold. This technique provides a measure of the smallest distance between two stimuli applied to the skin, where each is perceived as a separate stimulus (Jones & Lederman, 2006). The fingertips are most acute, with a two-point touch threshold of about 2-4 mm in neurologically intact individuals, whereas palmar skin can normally resolve two points separated by approximately 10-11 mm (Weinstein, 1968). More recently, more objective measures of spatial acuity have been developed. For example, Johnson and Phillips (1981) have proposed using a two-alternative forced-choice task in which participants are required to discriminate the orientation (vertical vs. horizontal) of a linear grating applied to the skin. Using this method, normal spatial resolution of the fingertips is approximately 1 mm. Overall, the skin has higher spatial resolving power than the ear, but is less acute than the eye (Sherrick & Cholewiak, 1986). Several studies have shown that spatial acuity declines with age in sighted individuals. For example, Legge, Madison, Vaugh, Cheong, and Miller (2008) used tactile acuity charts that require active exploration to assess spatial acuity of sighted and blind individuals aged 12 to 85 years old. They found that spatial tactile acuity declined almost 1% per year for the sighted, but not blind participants. Furthermore, this finding was attributed to the regular use of active touch on a daily basis by the blind, and not to past experience with Braille reading.

One way of assessing temporal acuity is by determining whether successive pulses applied to the skin of an observer are experienced as “one” pulse or “two” (Jones & Lederman, 2006). Pulses can either be generated mechanically or electrocutaneously. Normal temporal acuity for the former is about 5 ms (Gescheider, 1974), and about 50 ms for the latter (Higashiyama & Tashiro, 1988). The skin is more temporally acute than the eye, but less so than the ear (Lederman & Klatzky, in press).

2.1.2 Small tactile field of view

Haptic object perception is also constrained by the narrow tactile “field of view”, which has shown to be the size of a single fingertip (Lappin & Foulke, 1973; Loomis, Klatzky, & Lederman, 1981). This stands in contrast to the relatively large field of view for the visual system, which often permits simultaneous perception of entire visual scenes (Gibson, 1962). Because the size of many important objects frequently exceeds the tactile field of view, objects must be explored sequentially. In turn, sequential exploration not only takes more time than simultaneous extraction of object properties, but it also imposes large processing demands on working memory, and requires that information be integrated over space and time (Loomis, Klatzky, & Lederman, 1991).

Furthermore, widening the haptic field of view by exploring a surface with more than one finger is beneficial when processing real 3D objects, but much less so when exploring 2D surfaces, such as 2D raised-line drawings or Braille characters (Klatzky, Loomis, Lederman, Wake, & Fujita, 1993; Loomis et al., 1991; Lappin & Foulke, 1973). It is believed that real objects promote integration across fingers because they contain highly informative information in the third dimension (Klatzky et al., 1993)

2.1.3 The nature of manual exploration

In vision, a single brief, static glance often suffices for the apprehension of numerous object properties, such as shape, size, luminance, and color. In contrast, brief physical contact with a surface (a haptic “glance”) offers but a fraction of potentially haptically accessible information. In order to fully apprehend available cues, the haptic observer must dynamically manipulate object surfaces, sequentially carrying out a variety of specialized hand movements (Gibson, 1962; Lederman & Klatzky, 1987). For example, by rubbing the surface of a basketball, one can quickly learn about its texture and, to some degree, about its curvature (shape). However, a lifting motion is required to determine the ball's weight.

Lederman and Klatzky (1987) have comprehensively catalogued these specialized exploratory hand movements. Participants were asked to match multiattribute "nonsense" objects along specified haptically accessible dimensions (e.g. size and texture), and their hand movements were recorded. The authors found that haptic observers commonly employ particular hand movements to explore object surfaces. They called these stereotyped patterns "exploratory procedures" (EPs). Furthermore, one or more targeted object dimensions predicted the execution of each EP. For example, when participants were asked to match a "standard" object to a set of "comparison" objects based on "texture", they usually performed "Lateral Motion", an EP that involves a sheaing motion that involves rubbing the skin repeatedly back and forth across a surface.

Lederman and Klaztky (1987) also determined that each property is optimally extracted by a particular EP, and that this EP will be favored over others when exploration is unconstrained. As such, "Contour Following", which involves the sequential exploration of edges, was favored when exact shape was designated as the target property. Conversely, there was a bias to use “Pressure”, the application of normal force or torque to an object’s surface or axis, respectively, when participants desired to learn about surface compliance.

The need to execute a variety of EPs in order to glean different object attributes imposes several constraints on the apprehension of haptically salient information: each EP is associated with particular processing costs and benefits. These include precision, generality, duration, and compatibility.

Precision refers to how well a particular EP can convey different object properties. Some EPs are necessary for the extraction of particular object properties, whereas others are sufficient for transmitting certain object properties (i.e. at above-chance levels). For example, “Pressure” also provides above-chance information about texture and temperature (Lederman & Klatzky, 1987)

Generality refers to the number of object attributes than can be transmitted by performing a particular EP, other than those optimally associated with that EP, at above-chance levels (Klatzky & Lederman, 2008). Lederman and Klatzky (1987) calculated generality scores for each EP by counting the potential number of properties that can be perceived as a result of its execution. They found that some EPs offer the benefit of incidentally extracting more additional information than others. For example, statically pressing a large surface of skin against an object’s surface, an EP called “Static Contact”, is best suited for learning about surface temperature, but can also transmit additional coarse information about texture, volume, and global shape. However, molding one’s hand over the surface of an object to determine global shape and volume shape, an EP called “Enclosure”, sufficiently transmits information about an even greater number of object properties, such as texture, temperature, hardness, and weight (Klatzky & Lederman, 2008). “Contour Following” is the most general of all; however, it comes with many costs to haptic processing, as will be discussed in Section 2.2.

Duration refers to the amount of time required to execute an EP. Duration is positively related to processing costs (both motoric and cognitive): the longer the duration, the higher the costs (Klatzky, Lederman & Matula, 1993).

Finally, the benefit of performing certain EPs is their compatibility with other EPs. EPs are said to be compatible when they can be performed simultaneously without sacrificing the extraction of optimally associated object dimensions. An example of compatible EPs is stroking the surface of an object (Lateral Motion) to determine texture, while at the same time pressing down (Pressure) on the surface to determine compliance, or hardness (Lederman & Klatzky, 1987).

In conclusion, the haptic extraction of object attributes is inextricably bound to constraints that are inherent to haptic processing. In turn, these limitations are believed to influence the relative salience of object attributes.

2.2 Are some object properties more haptically salient than others?

Most haptically salient object attributes fall under one of two categories: material and geometric, with the exception of weight, which is a hybrid of the two. According to Lederman and Klatzky (under review), material properties are independent of a given object sample. They include texture (roughness), compliance (deformability under force), and thermal quality (temperature). Geometric qualities describe the structure of the same object sample, and include shape and size. Weight is coded both by an object's density (a material property), as well as volume (a geometric characteristic).

Several studies have demonstrated that material properties (texture, compliance, and temperature) are more haptically accessible and thus more salient than geometric properties (shape and size). Klatzky, Lederman, and Reed (1987) assessed the relative of salience of geometric and material object attributes using a free-sorting task. Participants were asked to sort objects based on what they subjectively perceived as similar dimensions, and their EPs were recorded. The objects were designed to vary equally along four dimensions: size and shape represented geometric properties, texture and hardness represented material properties. Furthermore, participants were assigned to one of four conditions designed to bias similarity judgments. In the first condition, participants were simply told to match objects based on their subjective judgment of similar object properties. In the second condition, they were explicitly told to match objects based on what each "felt" like. The third group of participants was asked to "visually imagine" each object before making their judgments. Finally, a fourth group was allowed to see the objects that they were sorting. The investigators found that participants chose to sort objects by similarity on the basis of their material attributes (texture and compliance) when vision was not available. Objects were sorted on the basis of their geometric properties (size and shape) when actual vision or visual imagery was employed.

This demarcation is not surprising if one considers the consequences of the aforementioned constraints imposed on haptic processing. Haptic extraction of geometric properties, such as an object’s exact shape, often requires that edges be explored sequentially (i.e. Contour Following). However, as previously mentioned, Contour Following is one of the costliest EPs: it imposes high demands on processing memory and spatio-temporal integration, is relatively slow, incompatible with other EPs, and often requires complex object manipulation (Klatzky & Lederman, 1991). Furthermore, in their analysis of EPs, Lederman and Klatzky (1987) noted that a greater number of exploratory hand movements optimally extract material rather than geometric information. As such, the haptic system is inherently biased to extract material properties. When vision is available, geometric properties are usually extracted by sight, while manual exploration is normally reserved for difficult material-based judgments that cannot be determined by the eye (Klatzky, Lederman, & Matula, 1993).

2.3 Implications of using 2D raised-line stimuli in haptic research

Constraints imposed on haptic processing have important implications for haptic research because the nature of haptic processing is highly dependent on the quality and quantity of cues available to the exploring hand. As such, these factors should be taken into account when selecting stimuli for haptic research.

Two-dimensional raised-line drawings, although relatively easy and inexpensive to produce, are challenging stimuli for haptic exploration. For one, this type of display is inherently devoid of many haptically salient material and geometric cues that are normally available in real 3D objects. Apprehension of raised-line shapes requires the execution of costly EPs, such as Contour Following. It is not surprising, then, that when Magee and Kennedy (1980) asked sighted, blindfolded participants to identify 2D raised-line representations of common objects, their accuracy was only 17%. However, when Lederman, Klatzky, and Metzger (1985) presented their participants with 100 3D common objects that could be held and freely explored, participants were able to identify 96% of the objects correctly, typically within only 2-3 seconds.

Second, perceiving shapes depicted in 2D raised-line graphics may rely more heavily on the haptic observer's past visual experience and ability to visually image than when 3D structures are processed. Lederman, Klatzky, Chataway, and Summers (1990) proposed that because 2D displays are so restricted in haptically salient cues, translating the haptic inputs into a visual image may facilitate processing. In their study, sighted (blindfolded), and congenitally blind participants haptically explored 22 raised-line pictures depicting familiar common objects. Evidence for the use of visual imaging was threefold. First, congenitally blind observers, who had no previous visual experience, were significantly less accurate than sighted observers. Second, objects that were subjectively rated as more difficult to mentally image were identified with lower accuracy than objects that were reportedly easier to image. Finally, participants who had a greater ability to mentally image (as measured by the Visual Vividness Imagery Questionnaire; Marks, 1973) performed significantly better than weaker imagers. Thus, haptic processing of 2D raised-line drawings may benefit from the use of visual processing channels.

But is visual imaging *necessary* for the perception of 2D raised-line drawings? Research suggests that, when available, past visual experience permeates haptic processing (Appelle, & Gravetter, 1985; Heller, 1993), but is not required. Evidence supporting this notion comes from studies showing that congenitally blind individuals are also capable of recognizing objects from 2D raised-line depictions (e.g. Heller, et al., 2002; Heller, 1989).

2.4 Section summary

In sum, touch can be used to extract geometric and material cues of surfaces and objects found in external environments. Haptic perception is inherently constrained by its spatial and temporal acuity, its small tactile field of view, and by the need to execute purposive exploratory procedures, most often in sequence. Together, these constraints create a bias toward the extraction and salience of material (cf. geometric) cues. When vision is available, touch is used to perform difficult material discriminations. Haptics is best suited to processing multiattribute, 3D objects, as opposed to their 2D raised-line depictions. Visual processing may or may not be involved during haptic processing, depending on the task demands.

As will be discussed in the sections that follow, researchers in the Touch Lab have recently demonstrated that both the identity and emotional expressions depicted on the human face, a highly significant class of common biological objects, can also be effectively processed haptically.

Chapter 3.0 Haptic face perception

Faces communicate information that is beneficial to an individual's survival and development. They contain cues to a conspecific's age, gender, and identity, as well as to their immediate attentional focus (Calder & Young, 2005; Langton, Watt, & Bruce, 2000). Furthermore, facial expressions of emotion can reveal a peer's mood, attitude, and intention at a faster rate than is verbally possible (Bruce & Young, 1986; Ekman, 1992; Izard, 1994).

Classically, face processing has been considered a visual phenomenon. However, a number of studies have now shown that haptic face perception is also possible. Live faces contain a number of haptically informative geometric cues such as 3D musculoskeletal structure, as well as material cues such as skin compliance, and temperature (Kilgour and Lederman, 2002). Furthermore, haptic face processing is possible even when many of the cues normally available in live faces are stripped away to create displays such as rigid 3D facemasks, or even simple 2D raised-line face drawings. In this section, issues that are relevant to the topic of haptic face perception will be discussed with an emphasis on haptic classification of facial expressions of emotion, the general topic of this thesis.

3.1 Face identity

According to Lederman, Klatzky, and Kitada (in press) faces constitute a category of objects, which at the basic level (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976), are easily distinguished from other common objects in our visual environment, such as other body parts, non-human faces, and inanimate objects. They can also be distinguished at an individual or subordinate level (Rosch, et al., 1976). Accordingly, visual face identification is a specialized and highly practiced skill, requiring the perception of minute variations among the hundreds of face exemplars encountered by the observer on a daily basis (Gauthier, Skudlarski, Gore, & Anderson, 2000). Interestingly, researchers have now shown that faces can also be distinguished by hand.

3.1.1 Haptic classification of face identity

Kilgour and Lederman (2002) were the first to demonstrate that face identity can also be determined by touch alone. In a match-to-sample task, blindfolded participants were required to haptically explore a target face and then haptically choose its match from one of three comparison faces. This task was performed by manually exploring both live faces and rigid 3D mask replicas. Untrained participants were able to perform with a surprisingly high level of accuracy: 80% for live faces and 60% for facemasks (chance = 33%). This was an impressive finding because it demonstrated that the haptic system could perform a task that required the ability to classify faces at the less-inclusive, subordinate level (Rosch, et al., 1976), a capability previously believed to be exclusive to the visual system. This finding has since been replicated by Pietrini et al. (2004), as well as by Casey and Newell (2005). Interestingly, Pietrini et al. (2004) showed that two congenitally blind participants were also able to haptically discriminate the identity of facemasks with 90% accuracy after only five hours of training.

Thus, face identity can be haptically determined from cues available in live faces, and to a lesser extent, in facemasks. On the other hand, it is much more difficult to identify faces when they are represented in 2D raised-line drawings, even with more substantial training. Participants in a learning task (McGregor, Klatzky, Hamilton, and Lederman, in press) were asked to name the identity of upright 2D face displays, and were given feedback following their response. The experiment consisted of 30 trials in total, spread over five learning locks. Overall accuracy was 33% at the start of the experiment (Block 1), increasing to 52% in Block 5 (chance = 17%), corresponding to an overall improvement of 60%.

3.2 Facial expressions of emotion

Faces signal more than identity. They also provide a malleable medium, ideal for dynamic social communication through the production and perception of facial expressions of emotion. These changeable facets of the human face were first studied empirically in the 19th century, by Charles Darwin. In his book, *The Expression of the Emotions in Man and Animals*, Darwin posited that facial expressions of emotion are innate, not learned. He based his hypothesis on the observation that human infants, congenitally blind individuals, different human races and cultures, and some non-human animal species, seemingly use similar facial movements to express the same state of mind (Darwin, 1872/1965; Izard, 1994). Nearly a century later, Darwin's ideas were re-popularized and re-evaluated by visual psychologists, such as Paul Ekman.

3.2.1 The six culturally universal facial expressions of emotion

In a series of classic studies, Ekman and colleagues had participants from different cultures and races, including individuals from a secluded tribe in Papua New Guinea, judge photographs of faces displaying a variety of facial expressions of emotion. Observers tended to attribute the same emotions to the same photographs, albeit consensus was not perfect (Ekman, Sorenson, & Friesen, 1969; Ekman, & Friesen 1971). Ekman subsequently posited that there are six universally recognizable facial expressions of emotion, namely: *anger, disgust, fear, happiness, sadness, and surprise* (Ekman, 1992). The production of these six primary facial expressions requires the use of unique musculoskeletal configurations. For example, sadness is typically characterized by a protruding lower lip, a down-turned mouth, and a slight furrowing of the forehead; surprise is associated with a dropped jaw, raised eyebrows, wide-open eyelids, and a horizontally wrinkled forehead (Ekman & Friesen, 1975).

The six primary emotions, designated by the *categorical* classification scheme pioneered by Ekman et al., have since become common tools for scientific investigations of emotion, and are well suited for the purposes of the current study. However, it is worth noting that the validity of this classification scheme is still debated and that several researchers have developed and adopted alternative ways of approaching the study of facial affect. For example, Katsikitis (1997) categorized facial expressions of emotion by determining where each expression fits along different *dimensions* relative to other emotions. She found that participants tended to judge facial expressions of emotion along two dimensions: pleasantness/unpleasantness, and lower-face/upper-face dominance. Furthermore, basic facial expressions of emotion are not totally universal: their presentation is affected both by the availability of visual feedback (Galati, Sini, Schmidt, & Tinti, 2003), as well as cultural group membership (Elfenbein & Ambady, 2003). In their dialect theory of emotion, Elfenbein and Ambady (2003) propose that communicating emotions using facial expressions is a universal language, but that this language consists of many cultural dialects.

3.2.2 Haptic classification of the six primary facial expressions of emotion

Interestingly, facial expressions of emotion can also be distinguished via manual exploration. In Lederman et al. (2007), young, sighted participants were blindfolded and asked to place their hands on the face of a live actor who, in turn, was trained to perform Ekman's six primary emotions on demand. The actor performed each expression of emotion both statically (the actor held the expression frozen on her face while the participant explored her face for up to 12 s), and dynamically (the actor performed up to four neutral-to-targeted expression cycles). Performance accuracy was 52% and 74% for static and dynamic displays, respectively (chance = 17%). Haptic performance also varied according to facial expression of emotion: happiness, surprise, and sadness were recognized at much higher accuracy levels than fear, disgust, and anger. In Baron (2008), the same six primary expressions of emotion were presented on life-like 3D plastic facemasks. Impressively, accuracy was 82% for upright displays, despite the absence of material cues normally available in live faces.

Recently, members of the Touch Lab have turned their attention to haptic processing of facial expressions of emotion in 2D raised-line facial displays. As discussed above, several past studies examining the ability to haptically distinguish common objects or face identity (Magee & Kennedy, 1980; McGregor, et al., in press) reported low recognition performance. The authors attributed these findings to the restricted nature of material cues and geometric cues found in 2D raised-line drawings. In turn, the spatially distributed raised contours available in these drawings are difficult to extract and integrate, posing a strain on spatio-temporal integration and memory. However, Lederman et al. (2008) recently reported that sighted blindfolded participants could haptically classify facial expressions of emotion in 2D raised-line drawings with significant success following a brief training period. Participants manually explored 2D raised-line depictions of the six basic facial expressions of emotion, plus a neutral face. Training consisted of two blocks of seven trials: 1) each emotion was labeled by the experimenter before it was shown, and 2) each emotion was presented in random order and feedback was provided following the participant’s response.

Facial emotions presented in an upright orientation were classified with 57% (Experiment 1), and 59% accuracy (Experiment 2; fear was excluded from analysis), where chance was 14%. Thus, 2D raised-line displays also have the potential to convey haptic information about facial expressions of emotion, albeit performance accuracy is somewhat lower than for live faces or facemasks due to more limited haptic cues. Why is it more difficult to haptically discriminate facial identity from 2D raised-line drawings than facial expressions of emotion? McGregor et al. (in press) suggest that emotional cues may be cruder than identity cues, and therefore more accessible for haptic processing. Furthermore, haptic classification of emotion may be easier because emotion categories are likely more familiar to the observer than particular face identities.

3.3 Section summary

Face processing is a bimodal perceptual phenomenon in which both face identity and facial expressions of emotion can be transmitted through the sense of touch at levels well above chance using live faces and facemasks, displays that offer a relatively diverse array of haptically accessible cues. In addition, Lederman et al. (2008) found that simpler facial expressions of emotion can be determined via manual exploration of 2D raised-line drawings.

Chapter 4.0 Current study

Face perception, such as the recognition of individual faces and the identification of facial expressions of emotion in live faces, plastic/clay facemasks, and 2D raised-line drawings, appears to be a bimodal perceptual phenomenon. Inasmuch as Lederman et al. (2008) found that facial expressions of emotion can be determined by exploring 2D raised-line drawings, with more extensive training participants may further enhance performance accuracy.

Given these findings, face perception may be possible even when no pattern vision is available, such as with blindness or severe visual impairment. That is, it may be possible for blind and visually impaired individuals to *haptically* decode facial expressions of emotion. To this author's knowledge, such a possibility has never been scientifically assessed. Instead, research has focused on determining the role of visual learning in the acquisition, development, and production of facial expressions of emotion (Galati, Miceni, & Sini, 2001). As such, studies have mostly concentrated on assessing the ability of blind individuals to produce facial expressions of emotion, as opposed to perceive and recognize them. One of the main findings reported in this line of research is that blind individuals produce spontaneous facial expressions that are very similar to those produced by the sighted. This result has been shown in adults, infants, and children of different ages (Galati, Ricci-Bitti, & Scherer, 1997; Galati et al., 2001; Castanho, & Otta, 1999; Galati et al. 2003). Conversely, when asked to deliberately produce a particular facial expression of emotion, or to act out an emotion facially, the resulting expressions are often less recognizable to sighted observers (Castanho, & Otta, 1999). Finally, some studies have suggested that blind individuals exert less control over their facial expressions of emotion. For example, in Galati et al. (2003), negative facial expressions, displayed by sighted 8 to11 year olds, were rated as more positive than negative emotions displayed by children of the same age who were blind from birth. The authors hypothesized that sighted individuals learn to mask socially undesirable emotions as they develop, and therefore possess greater control over their facial expressions of emotion than the early blind.

The present study extends initial findings on haptic classification of facial expressions of emotion (e.g., Lederman et al., 2007; Lederman et al., 2008; Baron, 2008) by now explicitly addressing the impact of training on the classification of facial expressions of emotion in 2D raised-line drawings by sighted, blindfolded, and blind haptic observers. We also extend findings by McGregor et al. (in press), whereby the accuracy of haptic classification of facial identity in 2D raised-line drawings significantly improved when subjects were given outcome feedback over 30 trials.

Given the considerable accuracy with which untrained participants in the Lederman et al. (2007) and Baron (2008) studies could identify facial expressions of emotion on live faces and 3D facemasks, respectively, a more challenging medium - 2D raised-line drawings - were used as face stimuli. By using 2D drawings, we hoped to maximize learning, while avoiding both floor and ceiling effects. Additionally, this type of stimulus display is interesting in its own right, because 2D raised-line depictions have the potential to convey emotions

(Lederman et al., 2008) despite lacking many of the material and more complex geometric cues available in live faces and facemasks.

A hybrid paradigm involving both pre-training/post-training and old/new test features was used for the experimental design. Participants were first tested on their ability to haptically classify six basic facial expressions of emotion with no training whatsoever. They were then extensively trained by the experimenter. Finally, they were re-tested, both on their ability to classify the drawings on which they were trained, as well as completely novel drawings of the same six expressions.

The current study was designed with three objectives is mind. The first objective was to evaluate sighted, blindfolded participants with no explicit training whatsoever in their ability to classify facial expressions of emotion by touch (Experiment 1). This had yet to been done: participants in Lederman et al. (2008) were provided with a modest amount of training before haptically classifying facial expressions of emotion on 2D raised-line drawings. However, no feedback was provided. Pre-Training performance was expected to be lower than the 57% accuracy reported by Lederman et al. (2008).

The second and primary objective of the current study was to explicitly address the effect of training on the haptic classification of facial expressions of emotion in 2D raised-line drawings (Experiment 1 and 3). McGregor et al. (in press) found that providing participants with outcome feedback significantly improved their ability to classify identify in 2D displays. Based on these findings, we expected that at least some learning would occur. However, we wished to empirically investigate the magnitude of such effects and the nature of the underlying learning processes. More specifically, will learning involve: 1) recognizing specific actor x emotion configurations only (i.e. "token-specific learning"), 2) recognizing more general representation for each category of facial expression (i.e., "generalization"), or 3) some combination of token-specific learning and generalization.

The third objective of this study was to explore how well individuals without pattern vision can haptically decode facial expressions of emotion (Experiment 3). Results for four case studies are reported, consisting of one congenitally blind and three adventitiously blind participants. To the extent that visual experience is important, we expected the congenitally blind participant to be less accurate than those with some previous sight.

Comparing haptic and visual face perception was not an explicit goal of the current study. However, Experiment 2 offers a vision control study with a small number of participants, permitting tentative comparison of the learning patterns for the two modalities. Given that face perception is normally performed visually, we expected higher overall accuracy for vision than for haptics.

The results for all three experiments will be discussed in the General Discussion.

4.1 Experiment 1- Haptic classification of facial expressions of emotion by sighted, blindfolded participants

This first experiment examined the ability of a large group of sighted, blindfolded participants to haptically classify facial expressions of six basic emotions in 2D raised-line displays. Pre-Training accuracy was established first (objective 1). The effect of training was subsequently assessed (objective 2).

4.1.1 Method

4.1.1.1 Participants

Sixty participants (17 males, 43 females, mean age = 19.75 years, SD = 3.43) were recruited through ads posted around the Queen's University campus and through the Queen's Introductory Psychology subject pool. Compensation was provided in the form of $15 or 1.5 credits towards an Introductory Psychology course. Participants reported normal (or corrected-to-normal) vision, hearing, and sensorimotor hand function, and no injuries to their hands or arms. A total of 54 participants were right-handed, five left-handed, and one ambidextrous. Handedness was assessed using the Edinburgh Handedness Inventory (Oldfield, 1971; Appendix A). The entire study took approximately 1.5 h to complete.

4.1.1.2 Materials

Four female actors (ages 69, 20, 22, and 29) were trained to produce six universal facial expressions of emotion (anger, disgust, fear, happiness, sadness, and surprise) based on those identified by Ekman & Friesen (1975) plus a neutral expression. Members of the Touch lab had to agree that their representations were appropriate. The actors' expressions were recorded with a digital camera. Next, the photographs were modified with Adobe Illustrator v10. Using the pencil tool, primary facial features (eyebrows, eyes, nose, mouth, and external facial outline) were traced with a “2 pt” line width. The photograph of the actor's face was then deleted so that only the traced facial features remained (see Fig 1). Two-dimensional, raised-line versions of the 28 faces were created by transferring the contour images onto 21 cm x 30 cm swell paper. This type of paper contains particles that burst when exposed to heat, and creates raised lines ~ 0.5 mm high and ~ 0.3 mm wide.

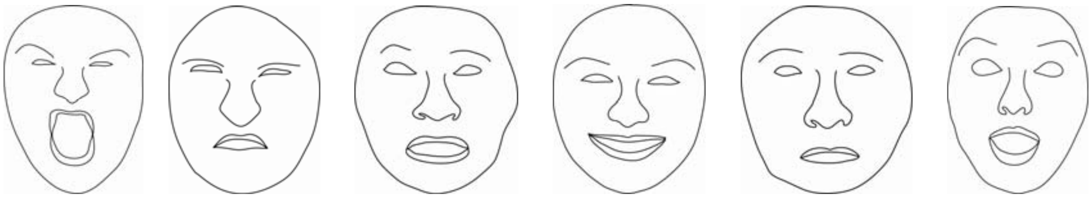

Figure 1. Examples of 2D raised-line face displays of emotion

The four neutral faces were used to familiarize participants with the task, but were not included in the formal study. The remaining 24 actor x emotion configurations (4 actors x 6 facial expressions of emotion) were used to create two pairs of mutually exclusive stimulus sets. The first pair of sets, Sets 1A and 1B, were created by quasi-randomly selecting two (of the four possible) configurations for each of the six facial expressions of emotion, and then adjusting the selections so that each actor appeared an equal number of times per set. In this way, each set contained 12 configurations, with each emotion represented twice and each actor represented three times. The 24 drawings were then re-pooled and re-divided to create the second pair of sets, Set 2A and Set 2B, as done to create the first pair. Using two pairs of stimulus sets in the formal experiment served to minimize the potential effect of set-specific idiosyncrasies.

A clipboard taped securely to a table was used to stabilize the raised-line drawings while these were being manually explored. Participants wore a blindfold and headphones with low-volume static noise during trials to block out visual and auditory cues. A cue sheet was created in Microsoft Excel by randomizing the order in which the stimuli were presented in each of the four Learning Components of the study. Participant responses and response times (in ms) were recorded using a custom-designed computer program called Experimenter Designer. A stopwatch was used to limit trial duration to the maximum response time of 45 s. Finally, a custom-designed questionnaire was created in Microsoft Word (Appendix A).

4.1.1.3 Experimental design

We used a mixed-model design with 1 between-subject factor and 2 within-subject factors. The between-subject factor was Set Assignment (4 levels: Assignment 1A/1B, 1B/1A, 2A/2B, and 2B/2A). Participants with Set Assignment 1A/1B were trained throughout on Set 1A faces, which was the Old set for this group. Then, a completely novel set, 1B, (New set) was introduced during the Post-Training phase of the experiment, randomly mixed in with drawings from the

Old set (see Figure 2). Conversely, participants with Set Assignment 1B/1A were trained throughout on Set 1B drawings (Old set) and were presented with Set 1A drawings as the New set stimuli. The same type of counterbalancing was used for participants with Set Assignment 2A/2B and 2B/2A, with Sets 2A and 2B now serving as the training and novel stimuli, respectively. Fifteen participants were assigned to each condition.

The two within-subject variables were Facial Expression of Emotion (six levels: anger, disgust, fear, happy, sad, surprise) and Learning Component (four levels: Pre-Training, Final-Training, Post-Training$_{\text{Old}}$ and Post-Training$_{\text{New}}$). Forty-eight trials were analyzed: each of the four Learning Components consisted of 12 trials (2 versions of each of the 6 emotions).

A hybrid experimental design was used, consisting of a pre-training/post-training paradigm, as well as an old/new paradigm (refer to Figure 2 throughout this section). The first stage of the learning paradigm was Pre-Training (12 trials). The purpose of this stage was to determine how well participants could haptically identify facial expressions of emotion portrayed in 2D raised-line drawings prior to training.

Four sub-stages of Training followed in sequence: Label-1 (12 trials), Feedback-1 (24 trials), Label-2 (12 trials), and Feedback-2 (12 trials), for a total of 60 Training trials. No accuracy data were collected during Label-1 and -2 because the experimenter named the emotion to the participant before the start of each trial. During Feedback-1 and -2, participants were required to respond and response data were collected; the experimenter then gave the correct name of the emotion. However, only Feedback-2 data were used in the final analysis (Final Training Learning Component) because learning effects attributable to Training would presumably be most apparent in this last sub-stage.

The Post-Training stage of the learning paradigm followed (24 trials). It also included an old/new learning paradigm: following Training, participants were tested on their ability to classify drawings belonging to the set on which they were trained (Old set), as well as a novel set (New set). The presentation of Old and New set drawings was randomized in this stage. However, for purposes of analysis, Old set data were separated from New set data, thus creating the Post-Training$_{\text{Old}}$ and Post-Training$_{\text{New}}$ Learning Components, respectively. Post-Training$_{\text{Old}}$ evaluated the participant's ability to classify the 12 actor x emotion configurations presented during Training (Old set), allowing the assessment of "token-specific learning". In Post-Training$_{\text{New}}$, participants were required to classify emotions portrayed in a completely new set of 12 actor x emotion configurations. This manipulation allowed us to assess "generalization", or the transfer of knowledge (acquired from the four sub-stages of Training) for the classification of 12 totally novel actor x emotion configurations (New set).

Because the stimuli belonged to closed sets of 12 (two versions of each emotion), we were concerned that if participants were presented with a stimulus set only once during each sub-stage of Training, they might begin to make classification judgments based on a process of elimination. In turn, this would reduce the value of chance for that sub-stage. To reduce the risk of this occurring, we deliberately varied the number of trials in the two Training sub-stages in which accuracy was recorded (24 trials in Feedback-1 and 12 trials in Feedback-2). The goal was to make it harder for participants to predict the end of a sub-stage and to use a counting strategy. This is also why the 12 Old set and 12 New set tokens were randomly intermixed and presented in a single Post-Training stage. However, for purposes of statistical analysis, they were subsequently separated into Post-Training$_{\text{Old}}$ and Post-Training$_{\text{New}}$ components.

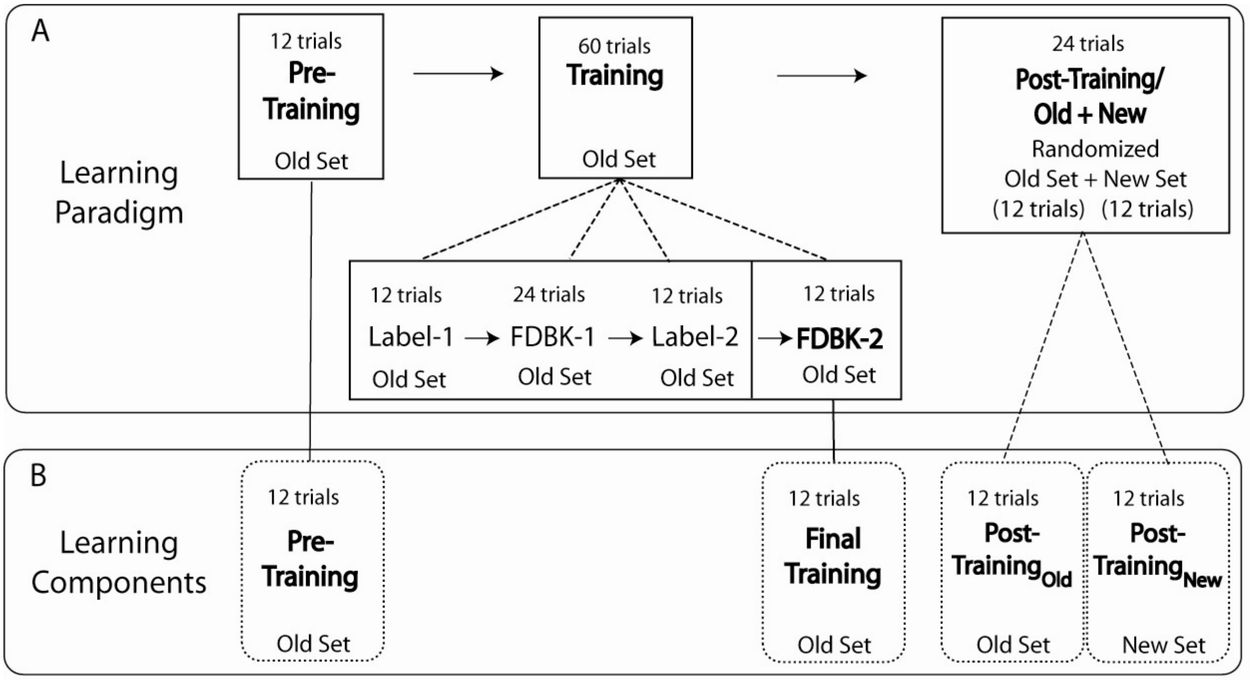

Figure 2. **A)** Stages of the learning paradigm: Pre-Training, Training (4 sub-stages), and Post-Training/New + Old; **B)** Breakdown of Learning Component (4 levels), the within-subject factor used to statistically assess learning

4.1.1.4 Procedure

Participants were first asked to wash their hands. They were then seated comfortably at a table and read a letter of information outlining the study. Next, they gave their consent to participate by reading and signing a consent form. A preliminary familiarization stage preceded the formal study. The formal study consisted of three stages: 1) Pre-Training, 2) Training (four sub-stages: Label-1, Feedback-1, Label-2, Feedback-2, 3) and Post-Training. Written instructions were provided before the start of the study, and before beginning new trial types, specifically, before the start of Pre-Training, and the first two sub-stages of Training (Label-1 and Feedback-1); verbal instructions were given before the start of Label-2, Feedback-2, and Post-Training.

Each trial began with the experimenter saying “start”, at which point the participant was free to start exploring the drawing placed in front of them in an upright position.

In the event that a trial reached 45 s, the maximum trial duration allowed, the experimenter said ‘stop’, and the participant was instructed to immediately remove his or her hands from the drawing. Stimulus presentation was randomized within each stage or sub-stage.

Preliminary Familiarization Stage

A drawing portraying a neutral facial expression was used to familiarize participants with the task and with the general layout of the stimuli. Participants explored the drawing for as long as they wished and practiced responding by removing their hands and saying ‘neutral’. The formal study followed.

Pre-Training Stage (12 trials)

During this stage, the experimenter presented each drawing in the Old set one at a time. Participants were asked to identify the facial expressions portrayed by the drawings as quickly and accurately as possible and were given no feedback following their response.

Training Stage (four sub-stages; 60 trials total)

1) Label-1 (12 trials) The Old set was then presented a second time. However, during this sub-stage, the experimenter labeled the expression portrayed in each drawing before allowing the participant to explore it. The participant was instructed to learn what each expression felt like. The trial ended when the participant removed his or her hands from the drawing.

2) Feedback-1 (24 trials) As during the Pre-Training stage, participants were asked to identify the expressions as quickly and accurately as possible. Unlike the Pre-Training stage, however, the experimenter now provided feedback by naming the expression following the participant’s response. Also, the Old set was presented twice during this sub-stage.

3) Label-2 (12 trials) The procedure for this sub-stage was identical to the procedure of the Label-1 sub-stage.

4) Feedback-2 (12 trials) This sub-stage was a repetition of Feedback-1, but consisted of a single presentation of the Old set.

Post-Training (24 trials)

This Learning Component was carried out much like the Pre-Training stage in that emotions were not labeled, and participants were not given feedback following their response. However, this stage was unique in that it included a randomly mixed presentation of the Old and New set (see Figure 2).

A 5 min break was provided following the Feedback-1 sub-stage. Upon completion of the main study, participants were asked to fill out a handedness inventory and questionnaire. Finally, they read a debriefing letter. All of the forms and instructions associated with this experiment are found in Appendix A.

4.1.2 Results

The alpha level for ANOVAs and for the Bonferroni pairwise tests was set at .05. The Greenhouse-Geisser correction procedure was used when Mauchly's test of Sphericity was violated. All significant effects and interactions were analyzed post-hoc using Bonferroni pairwise tests. One-tailed t-tests were used to make comparisons against chance. Unless meaningful to the discussion, non-significant results are not reported.

4.1.2.1 Accuracy

Participant responses were coded 1 (correct) or 0 (incorrect). The mean accuracy for each emotion at the Learning Component level was then calculated for each participant.

A preliminary three-factor mixed-model ANOVA was performed to check for significant effects of Set Assignment. Set Assignment (4 levels) was the between-subject factor; the two within-subject factors were Learning Component (4 levels) and Emotion (6 levels). The main effect of Set Assignment was not significant. There were two significant interactions involving this term: Learning Component x Set Assignment, and Learning Component x Emotion x Set Assignment. However, both interactions had small effect sizes (η^2= .14, and .08, respectively) relative to the effect sizes for the primary factors of interest, Learning Component and Emotion (η^2 = .64, and .56, respectively), and are not interpretable in any meaningful way. For this reason, Set Assignment was not included as a factor in additional analyses, and will not be discussed further.

Next, we performed a two-way, within-subject, repeated measures ANOVA. The factors were Learning Component (4 levels) and Emotion (6 levels). The main effect of Learning Component was highly significant $F(3, 177) = 88.44$, $p < .001$, $\eta^2 = .60$. As can be seen in Figure 3, accuracy was significantly lower for the Pre-Training Learning Component than for either Final Training or Post-Training$_{\text{Old}}$, *p*s < .001, or for Post-Training$_{\text{New}}$, $p < .05$. This represents an improvement of 81% from Pre-Training to Final Training, 76% from Pre-Training to Post-Training$_{\text{Old}}$, and 20% from Pre-Training to Post-Training$_{\text{New}}$. Also, performance was significantly lower for Post-Training$_{\text{New}}$ than for either Final Training or Post-Training$_{\text{Old}}$ (*p*s < .001).

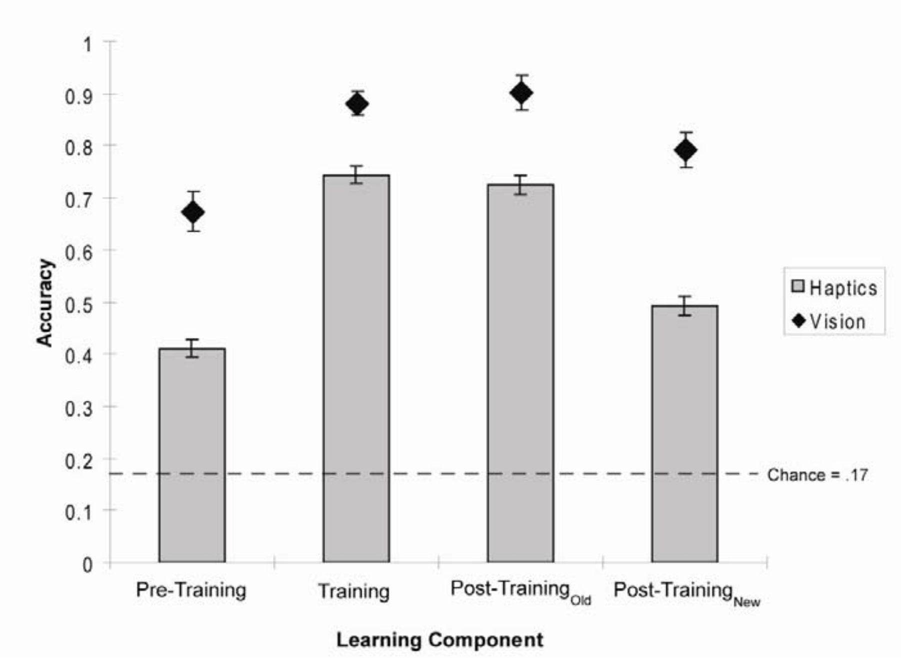

Figure 3. Mean classification accuracy (SEM) as a factor of Learning Component for Experiment 1 (haptics) and Experiment 2 (vision)

The main effect of Emotion was also highly significant F(5, 295) = 70.65, *p* < .001, $\eta^2 = .55$. The order of performance for expressions of emotion from best to worse was: happiness and surprise, followed by anger and sadness, and finally, disgust and fear (Figure 4).

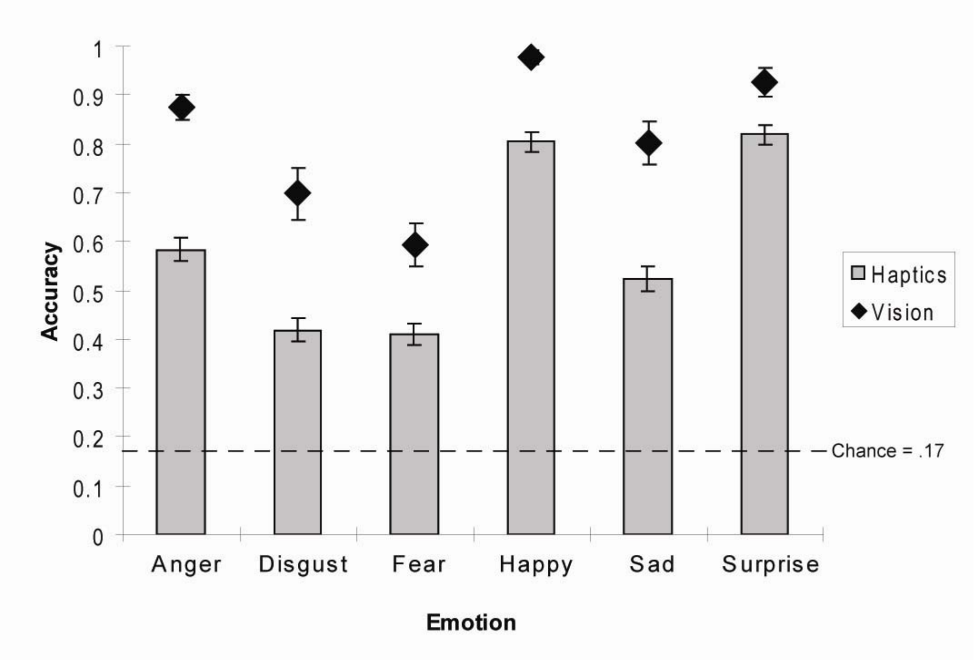

Figure 4. Mean (SEM) classification accuracy as a factor of Emotion for Experiment 1 (haptics) and Experiment 2 (vision)

Finally, the Learning Component x Emotion interaction was significant *F*(15, 885) = 8.18, *p* < .001, although effect size was relatively small, $\eta^2 = .12$. Almost all six emotions followed a common pattern of behavior across the four Learning Components: a low accuracy at Pre-Training, significant improvement in Final Training and Post-Training$_{\text{Old}}$, and a drop in accuracy at Post-Training$_{\text{New}}$ with performance levels similar to those for Pre-Training. This trend is well represented by each emotion's mean percent improvement score from Pre-Training to 1) Final Training, 2) Post-Training$_{\text{Old}}$, 3) and Post-Training$_{\text{New}}$, as shown in Table 1. The *p* values were obtained from corresponding post-hoc pairwise comparisons in the general ANOVA. However, there were three notable exceptions to this general trend: 1) Pre-Training accuracy for surprise and happiness was very high (81% and 77%, respectively), 2) surprise and happiness did not show any significant improvement in accuracy with training, and 3) anger and sadness were the only two emotions that were recognized more accurately in Post-Training$_{New}$ than in Pre-Training.

Table 1

Experiment 1: Mean Percent Improvement by Emotion from Pre-Training to Post-Training$_{Old}$ and Post-Training$_{New}$

			Emotion			
Learning Components Compared	Anger	Disgust	Fear	Happiness	Sadness	Surprise
Post-Training$_{Old}$ with Pre-Training	421%**	125%**	129%**	15%	163%**	9%
Post-Training$_{New}$ with Pre-Training	258%**	25%	4%	-8%	78%*	-16%

** $p < .001$
* $p < .01$

Finally, a T-test against chance revealed that Pre-Training accuracy for anger, disgust, and fear was no greater than chance. Also, fear accuracy was not above chance levels in Post-Training$_{New}$.

4.1.2.2 Error Analysis

Stimulus-response confusion matrices present error results for the four Learning Components: Pre-Training (Table 2), Final Training, (Table 3), Post-Training$_{Old}$ (Table 4), Post-Training$_{New}$ (Table 5). In order to compensate for possible response bias, confusion scores were normalized within each column by dividing them by the total number of times each facial expression of emotion was identified. Not surprisingly, learning resulted in fewer confusions in Final Training and Post-Training$_{Old}$ than in Pre-Training or Post-Training$_{New}$. Generally speaking, there were more confusions for disgust, fear, and sadness than for the other emotions. Furthermore, these expressions were often confused with each other. Disgust was also confused with anger and surprise. Anger was highly confused with surprise in Pre-Training, and to a lesser extent, with disgust and fear. However, learning effects for anger were apparent by the reduction of confusions in the subsequent stages of the experiment relative to Pre-Training.

Table 2

Error proportions for Pre-Training: confusion matrices normalized within each column. Bold values along the diagonal indicate correct responses. Confusions ≥ .15 are italicized

	Response					
Stimulus	Anger	Disgust	Fear	Happy	Sad	Surprise
Anger						
Freq	**19**	*18*	*14*	9	2	*58*
%	**.20**	*.17*	*.15*	.07	.02	*.28*
Disgust						
Freq	*30*	**28**	*17*	2	*25*	18
%	*.32*	**.27**	*.19*	.02	*.26*	.09
Fear						
Freq	*17*	*18*	**28**	10	*36*	11
%	*.18*	*.17*	**.30**	.08	*.38*	.05
Happy						
Freq	8	9	3	**92**	0	8
%	.09	.09	.03	**.72**	.00	.04
Sad						
Freq	*18*	*31*	*18*	6	**32**	15
%	*.19*	*.30*	*.20*	.05	**.34**	.07
Surprise						
Freq	2	0	12	9	0	**97**
%	.02	.00	.13	.07	.00	**.47**
Total # of Responses	94	104	92	128	95	207

Table 3

Error proportions for Final Training: confusion matrices normalized within each column. Bold values along the diagonal indicate correct responses. Confusions ≥ .15 are italicized

	Response					
Stimulus	Anger	Disgust	Fear	Happy	Sad	Surprise
Anger						
Freq	**94**	11	4	2	0	9
%	**.73**	.10	.03	.02	.00	.07
Disgust	16	**75**	7	2	*20*	0
Freq	.13	**.66**	.06	.02	*.16*	.00
%						
Fear	4	9	**76**	2	*26*	3
Freq	.03	.08	**.64**	.02	*.21*	.02
%						
Happy	7	4	4	**103**	0	2
Freq	.06	.04	.03	**.92**	.00	.02
%						
Sad	3	2	*22*	2	**79**	0
Freq	.02	.12	*.19*	.02	**.63**	.00
%						
Surprise						
Freq	4	0	6	1	0	**109**
%	.03	.00	.05	0.01	.00	**.89**
Total # of Responses	128	113	119	112	125	123

Table 4

Error proportions for Post-Training$_{\text{Old}}$: confusion matrices normalized within each column. Bolded values along the diagonal indicate correct responses. Confusions ≥ .15 are italicized

	Response					
Stimulus	Anger	Disgust	Fear	Happy	Sad	Surprise
Anger						
Freq	**99**	7	5	3	0	6
%	**.74**	.06	.05	.02	.00	.05
Disgust						
Freq	19	**63**	13	2	*23*	0
%	.14	**.56**	.12	.02	*.18*	.00
Fear						
Freq	2	*26*	**64**	7	*19*	2
%	.02	*.23*	**.59**	.06	*.15*	.02
Happy						
Freq	6	2	2	**107**	1	2
%	.05	.02	.02	**.86**	0.01	.02
Sad						
Freq	2	14	*19*	2	**83**	0
%	.02	.12	*.18*	.02	**.66**	.00
Surprise						
Freq	5	1	5	3	0	**106**
%	.04	0.01	.05	.02	.00	**.91**
Total # of Responses	133	113	108	124	126	116

Table 5

Error proportions for Post-Training$_{\text{New}}$: confusion matrices normalized within each column. Bolded values along the diagonal indicate correct responses. Confusions ≥ .15 are italicized

	Response					
Stimulus	Anger	Disgust	Fear	Happy	Sad	Surprise
Anger						
Freq	**69**	*20*	10	6	0	15
%	**.50**	*.17*	.10	.05	.00	.14
Disgust						
Freq	*32*	**35**	*13*	1	*36*	*3*
%	*.23*	**.29**	*.13*	0.9	*.27*	*.30*
Fear						
Freq	7	*31*	**28**	13	*37*	4
%	.05	*.26*	**.27**	.11	*.28*	.04
Happy						
Freq	10	12	7	**85**	2	4
%	.07	.10	.07	**.73**	.02	.04
Sad						
Freq	5	*21*	*33*	3	**57**	1
%	.04	*.17*	*.32*	.03	**.43**	0.01
Surprise						
Freq	16	2	12	8	1	**81**
%	.12	.02	.12	.07	0.01	**.75**
Total # of Responses	139	121	103	116	133	108

4.1.2.3 Response time

The same Learning Component x Emotion ANOVA was performed, this time with response time as the dependent variable. There was a significant effect of Learning Component $F(3, 177) = 47.28$, $p > .001$, $\eta^2 = .45$. As can be seen in Figure 5, participants took significantly longer to respond in Pre-Training than in the three subsequent Learning Components (all *p*s < .001). Also, reaction time for Post-Training$_{New}$ was longer than for either Final Training or Post-Training$_{Old}$, which were equal in duration.

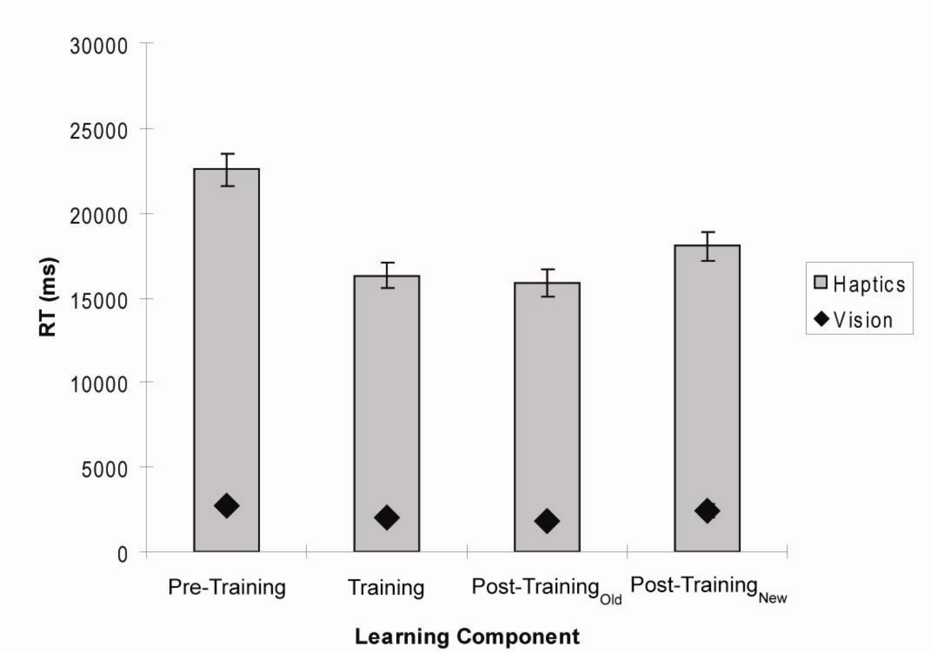

Figure 5. Mean response time (SEM) as factor of Learning Component for Experiment 1 (haptics) and Experiment 2 (vision) be consistent throughout

The main effect of Emotion was also highly significant $F(5, 295) = 29.28$, $p > .001$, $\eta^2 = .33$ Happiness and surprise were recognized faster than the other four facial expressions of emotion, which were statistically equivalent (all *p*s < .001, except for anger vs. happiness, $p < .01$) (Figure 6).

Out of the total 2880 trials that comprised the four Learning Components (i.e. Pre-Training, Final Training, Post-Training$_{Old}$, Post-Training$_{New}$), 137 were stopped by the experimenter at 45 s (i.e. at the maximum response time), or ~ 5%. Given the low percentage of stopped trials, the RTs for these trials were included in the analysis using values of 45 s.

A correlation analysis comparing accuracy with response time was also performed at the participant level (i.e. mean accuracy vs. mean response time for each participant). Although this relationship was in the expected negative direction, it was not statistically significant. This may have been due to the high variability of response time values and to the fact that 5% of the trials were assigned 45 s as they reached the maximum exploration time permitted.

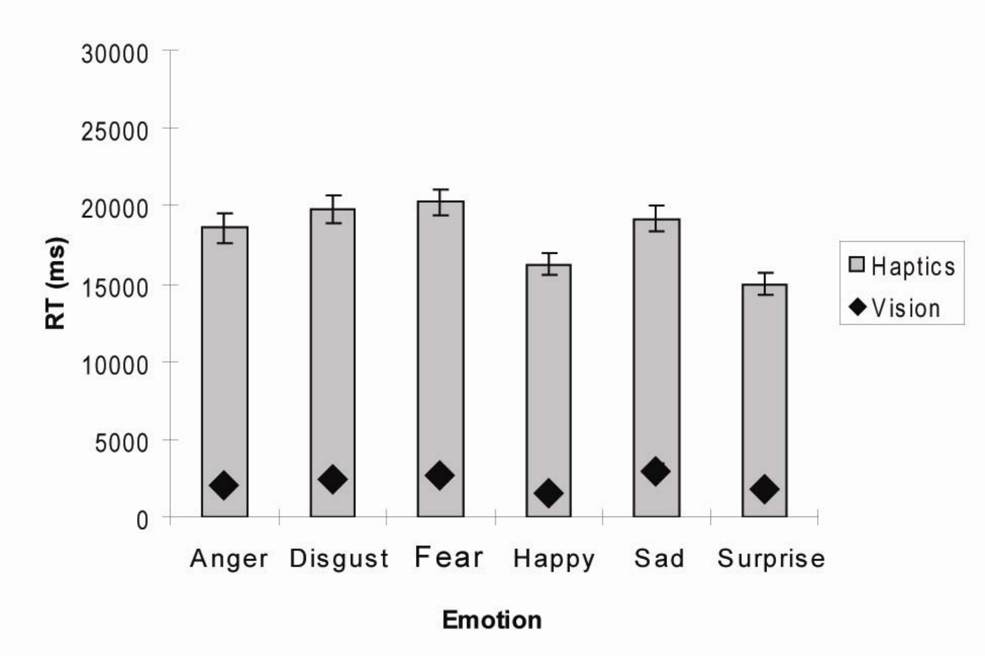

Figure 6. Mean response time (SEM) as a factor of Emotion for Experiment 1 (haptics) and Experiment 2 (vision)

4.2 Experiment 2- Vision control study: visual classification of facial expressions of emotion by a small group of sighted participants

The purpose of Experiment 2 was to permit comparison of visual and haptic learning patterns (Experiment 1) using the same drawings.

4.2.1 Method

4.2.1.1 Participants

Twelve participants (1 male, 11 female, mean age = 18.4 years, *SD* = 0.52) were recruited through ads posted around the Queen's University campus and through the Queen's Introductory Psychology subject pool. Criteria for participation were identical to those for the haptic study. All of the participants were right-handed. Participants from the haptic study (Experiment 1) were not allowed to participate in the vision study (Experiment 2) and vice versa. Participants received $10 or 1.0 credit towards an Introductory Psychology course. The entire study took approximately one hour to complete.

4.2.1.2 Materials

The same 28 raised 2D contour drawings of six facial expressions of emotion and neutral faces that were used in the haptic study (Experiment 1) were reproduced on white paper (21.60 cm x 27.90 cm) as black line contours ~ 1 mm wide. During trials, drawings were held by a clipboard taped to a surface with an incline of about 30°. Participants wore a pair of liquid crystal (LCD) glasses (PLATO$^{\text{TM}}$), the lenses of which were cleared by the experimenter with the press of a button at the start of each trial and turned opaque when the trial was completed. The remaining materials were the same as those used in the haptic study.

4.2.1.3 Experimental design and Procedure

The experimental design and procedure used for this study were almost identical to those used in the haptic study (Experiment 1). However, in this experiment, participants performed the task visually rather than haptically. Trials began when the experimenter cleared the lenses of the LCD glasses and ended when the participant responded, at which point their glasses were rendered opaque. Forms and instructions associated with this experiment can be found in Appendix B.

4.2.2 Results

4.2.2.1 Accuracy

A two factor, repeated-measures ANOVA was performed with Learning Component (4 levels) and Emotion (6 levels) as the independent variables, and accuracy as the input factor. The effect of Learning Component was statistically significant $F(3, 33) = 10.81$, $p < .001$, $\eta^2 = .50$ (see Figure 3). As in the haptic study (Experiment 1), Pre-Training accuracy was significantly lower than either Final Training or Post-Training$_{\text{Old}}$ accuracy (ps < .01), which were not statistically different. However, unlike the haptic study, Post-Training$_{\text{New}}$ accuracy was not statistically lower than Post-Training$_{\text{Old}}$. Also, Post-Training$_{\text{New}}$ was not significantly higher than Pre-Training, but the trend was in the same direction.

The main effect of Emotion was also highly significant $F(5, 55) = 16.57$, $p < .001$, $\eta^2 = .60$. As shown in Figure 4, anger, happiness, and surprise were classified more accurately than disgust ($p < .05$, .01, .05, respectively) and fear ($p < .01$, .001, .005, respectively).

Finally, the Learning Component x Emotion interaction was also statistically significant $F(15, 165) = 2.16$, $p < .05$, $\eta^2 = .16$. Learning effects were limited for anger, happiness, sadness, and surprise because they were often classified with perfect accuracy by the end of the Training stage (Final Training). On the other hand, learning was readily observable for fear and disgust, and the learning trend closely resembled haptic classification of these emotions (Experiment 1) across Learning Components in that accuracy was: 1) lower in Pre-Training relative to the other emotions, 2) increased significantly in Final Training and Post-Training$_{\text{Old}}$, and 3) dropped again to Pre-Training levels in Post-Training$_{\text{New}}$.

A t-test against chance revealed that in the Pre-Training Learning Component, participants were not able to classify fear with above-chance accuracy (.17).

4.2.2.2 Response time

A second Learning Component x Emotion ANOVA was performed using the participants' response time as the dependent variable. Once again, there was a significant main effect of Learning Component $F(2.06, 22.70) = 5.87$, $p < .01$, η^2

= .35. As in the haptic study, participants took longer to respond during Pre-Training (*M* = 2.74 s, *SEM* = .32 s) than during either Final Training (*M* = 2.00, *SEM* = .21) or Post-Training$_{\text{Old}}$ (*M* = 1.82 s, *SEM* = .20 s ; *p*s = .009, .03, respectively), which were not statistically different. Unlike the haptic study, Post-Post-Training$_{\text{New}}$ response times did not differ significantly from the other three Learning Components. This effect is shown in Figure 5.

The main effect of Emotion was also statistically significant *F*(2.5, 27.45) =10.90, *p* < .001, η^2 = .50 (see Figure 6). As in the haptic study (Experiment 1), participants took longer to identify disgust, fear, and sadness than happiness (all *p*s < .03) and surprise (*p*s < .05).

4.3 Experiment 3 – Haptic classification of facial expressions of emotion by four blind individuals

The following case studies with four blind individuals (three adventitious and one congenital) offer a tentative assessment of the effect of limited visual experience on the ability to haptically classify facial expressions on 2D raised-line drawings (objective 3).

4.3.1 Method

4.3.1.1 Participants

Four blind individuals were recruited through a personal contact of the Touch Lab. Table 6 provides their demographic information, as well as the history and nature of their visual loss.

Table 6

Experiment 3: Blind participant characteristics

Participant	Age	Gender	Highest Level of Education Attained	Visual Capacity	History of Visual Loss
RH	19	F	Undergraduate	Some light perception in both eyes	Gradual loss since birth due to genetic disease
SC	19	F	Undergraduate	None in either eye	Cancer at 5 months with gradual loss until 14 years of age
KB	34	F	Post-Graduate (Law)	None in right eye; 10% in left eye	Congenital Glaucoma; some vision in right eye until 25 years of age
SK	61	F	High School Diploma	None in either eye	Retinopathy of Prematurity; Complete loss of vision within 3 months following birth

4.3.1.2 Materials

The materials were identical to those used in the haptic study (Experiment 1) involving sighted individuals with the exception that the blind participants were not blindfolded. KB, who had some residual light perception, wore the same LCD glasses as subjects in the Vision study. RH could also perceive light, but her eyes were not covered because she felt that wearing the glasses would be uncomfortable.

4.3.1.3 Experimental design and Procedure

The experimental design and procedure were almost identical to those used in the haptic study with sighted subjects. However, here all four participants had their hand function assessed prior to commencing the formal study. This was done to ensure that this special population had normal hand function. Were they to show poor haptic processing of facial expressions of emotion, their performance could have been attributed to impaired hand function, as opposed to loss of vision. Tests of hand function included the 2-point touch test for spatial acuity and the Von Frey filament test for force sensitivity, both of which used the Method of Limits (with 5 alternating ascending and descending series, each terminating after 5 changes in direction), and haptic common object identification (for further procedural details, see Kilgour, deGelder, & Lederman, 2004). Forms and instructions associated with this experiment can be found in Appendix C.

4.3.2 Results

4.3.2.1 Tests of hand function

Threshold results for 2-point touch spatial acuity and pressure sensitivity (individual thresholds based on the mean of the values corresponding to five changes in each direction) are shown in Table 7. SC, KB, and SK correctly classified all 17 objects correctly in the haptic object identification task. RH gave one incorrect answer: she mislabeled a wine cork as a “game piece”. The mean response time for all four participants was ≤ 2 s. These results are indicative of normal hand function (see Jones & Lederman, 2006).

Table 7.

Mean 2-Point Touch and Pressure Sensitivity Thresholds

	2-Point Touch (mm)		Force Sensitivity (g)	
	Hand		Hand	
Participant	Left	Right	Left	Right
RH	3.04	2.68	.008	.008
SC	2.24	2.72	.008	.008
KB	4.04	3.52	.008	.008
SK	4.16	3.72	.018	.019

4.3.2.2 Accuracy

Formal statistical calculations by either individual or group were inappropriate for several reasons: 1) the small sample size of this group, 2) the heterogeneous nature of visual impairment in this sample, 3) the discontinuous nature of accuracy data due to the fact that each emotion was only presented twice within each Learning Component.

However, it is notable that when each participant’s accuracy is plotted as a function of Learning Component (Figure 7), the emerging learning curves resemble the mean learning trend for sighted participants (thick dark line). As with sighted participants, RH, SC, and SK show an improvement in accuracy for both Post-Training$_{\text{Old}}$ and Post-Training$_{\text{New}}$ relative to Pre-Training.

As can be seen in Figure 7, the learning trends for SK and KB are noticeably different than those for the sighted, or for RH and SC. SK performed the task with lower accuracy than the others. This finding can presumably be attributed to the fact that she was born totally blind, and had no experience with visual or haptic face perception. On the other hand, it is more difficult to explain KB's unique learning trend. Although she was able to classify facial expressions of emotion with a high level of accuracy in Pre-Training, her performance actually decreased in Post-Training$_{\text{Old}}$ and Post-Training$_{\text{New}}$. The experimenter did not observe any obvious differences in the way that KB performed this task, and is unable to explain the decline.

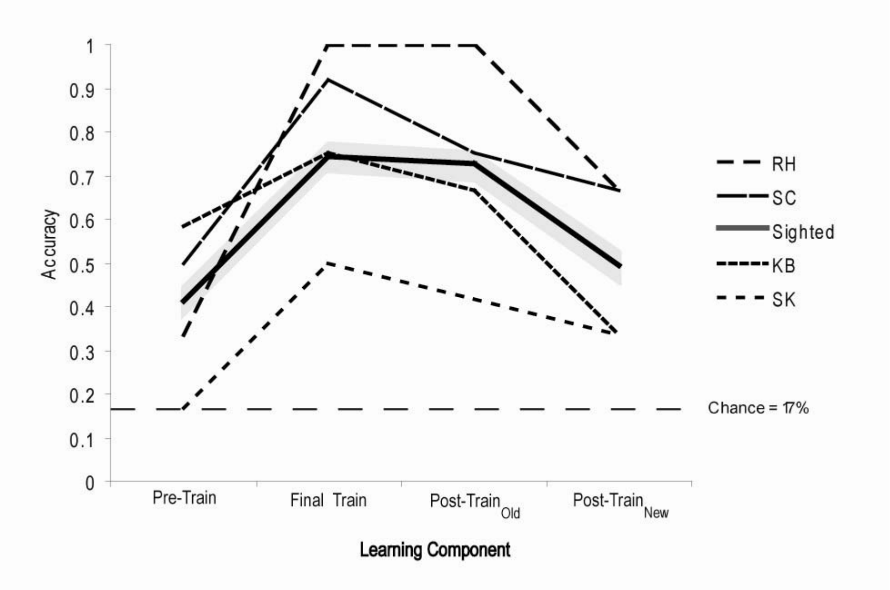

Figure 7. Mean accuracy of individual blind participants (Experiment 3) and of the sighted group (shaded area represents ± 95% confidence intervals; Experiment 1) as a function of Learning Component

4.3.2.3 Response Time

As with accuracy, no statistical tests were performed for similar reasons. Figure 8 demonstrates that three of the blind participants (RH, SC, and KB) performed the task notably faster than the sighted subjects. SK's mean response time was closer to that of the average sighted person.

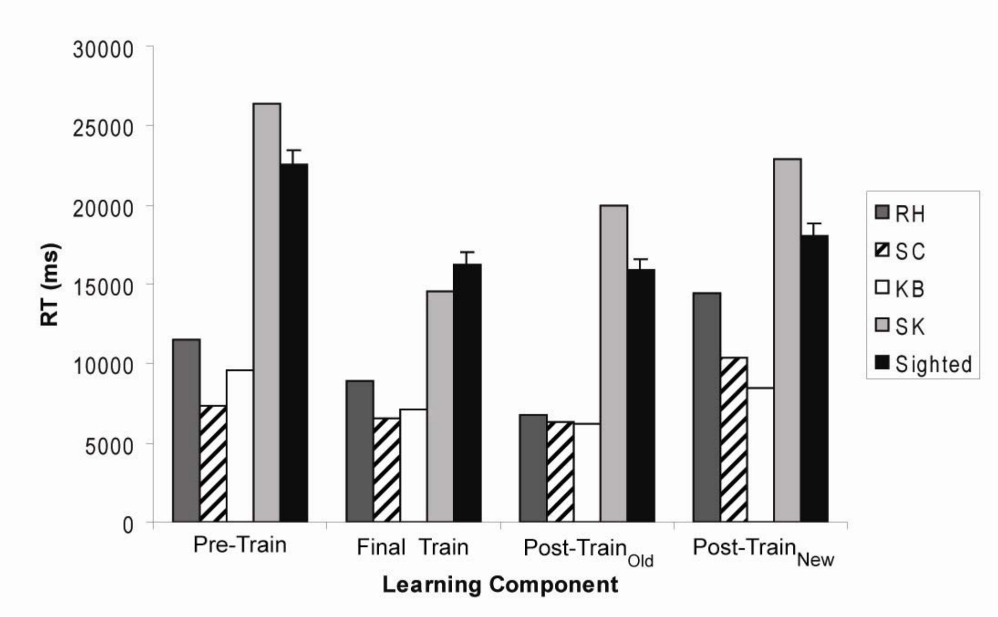

Figure 8. Mean response time of individual blind participants (Experiment 3) and of the sighted participant group (Experiment 1; SEM) as a factor of Learning Component

4.4 General Discussion

4.4.1 How well can people haptically identify facial expressions of emotion in 2D raised-line drawings prior to training?

In Lederman et al. (2008), sighted blindfolded participants classified six basic emotions plus a neutral expression in 2D raised-line drawings with 57% accuracy after 14 trials of training. The first goal of the current study was to measure performance accuracy for completely untrained sighted blindfolded participants.

Overall, mean performance accuracy for Pre-Training was 41% for the haptic condition (Experiment 1). Surprise and happiness were classified remarkably well (81% and 77%, respectively). On the other hand, three emotions (anger, disgust, and fear) were classified at chance levels (17%); sadness was also relatively low (26%).

The high Pre-Training performance for happiness and surprise indicates that observers successfully utilized stored information about these expressions to interpret their haptic percepts. Past visual experience with facial expressions of emotion is the most likely source of this knowledge, given that haptic exploration of facial expressions of emotion is doubtless rare outside of the lab. The effect of such visual experience was probably twofold. First, it may have encouraged visual mediation: participants may have translated their haptic perceptions into visual images and further interpreted these via visual channels. Second, haptic inputs may have been interpreted based on higher-level knowledge about the unique feature (or feature set) that represents each emotion derived from past visual experience. Another possibility is that cognitive representations of facial affect are formed directly from the afferent somatosensory signals available during an individual's own production of facial expressions of emotion, or through a lifetime of touching one's own face.

Why were happiness and surprise the only high-performance emotions at Pre-Training? Given the lack of familiarity with this haptic task, observers probably utilized a pre-formed cognitive representation of each facial expression of emotion to interpret the incoming signals from the exploring hand. One or two highly distinctive feature(s) are probably sufficient: (happy: bulging cheeks, upturned lips; surprise: wide open mouth, brows raised and furrowed brow, etc). Classification success was probably contingent on the availability of such representations, and on the ease with which they could be accessed and compared to incoming haptic inputs. It is possible, then, that representations of happiness and surprise were more available and accessible than the other four emotional expressions. Visual imagery may also have facilitated this process. This hypothesis is in line with Lederman et al. (1990), who found that when sighted blindfolded participants were asked to haptically identify 2D raised-line drawings of 22 common objects, accuracy was significantly correlated with both object imageability, as well as with the observer's ability to visually image (measured by the VVIQ test; Marks, 1973).

In Experiment 2, a small group of new participants performed the same task visually. The mean Pre-Training accuracy for this group was 67% (cf. 41%

for haptics). That vision outperformed haptics was a predictable finding for the following reasons: 1) humans are experts at processing faces visually but not haptically (Lederman, Kilgour, Kitada, Klatzky, & Hamilton, 2007), and 2) as previously discussed in Section 2.0, the geometric contour information available in 2D raised-line drawings is more efficiently apprehended by the visual system, as compared to the haptic system due to inherent constraints in haptic processing (Lederman et al., 1990).

4.4.2 Did learning occur? If so, what was learned?

The main purpose of this study was to assess the effect of training on the haptic classification of facial expressions of emotion in 2D raised-line drawings, and to examine the nature of the underlying learning processes. We asked: to the extent that accuracy increased with training, did participants learn to associate particular drawings with the correct emotion label (i.e., was learning token-specific) and/or did participants learn to recognize characteristics shared by expressions belonging to the same emotion category (i.e. did learning generalize)? A pre-/post-training paradigm was used in combination with an old/new paradigm, where, following extensive training, participants were tested on their ability to classify emotions depicted in drawings on which they were trained (Post-Training$_{\text{Old}}$), as well as on completely novel examples of each emotion (Post-Training$_{\text{New}}$). We concluded that generalization had occurred if subsequent to training, participants could classify novel displays (New set) of the same six emotions (Post-Training$_{\text{New}}$) better than prior to training (Pre-Training).

As expected, overall accuracy in Experiment 1 improved significantly from Pre-Training (41%) to Post-Training$_{\text{Old}}$ (73%), a mean relative improvement of 76%. There were two exceptions to this finding: happiness and surprise did not improve with training. However, they were consistently classified more accurately than the other four emotions (except anger in Post-Training$_{\text{Old}}$). This may be attributable to ceiling effects: in Pre-Training, on average happiness and surprise were already classified perfectly by 57% and 68% of participants, respectively. Furthermore, the restricted nature of haptic cues available in 2D raised-line displays may have further created an artificial ceiling effect. The limited information available in the displays may have already been exhausted during Pre-Training, thereby limiting the potential for further learning. However, the overall increase in accuracy from Pre-Training to Post-Training$_{\text{Old}}$ clearly indicates that learning occurred.

Accordingly, we further asked about the nature of the underlying haptic learning process(es). The results were somewhat mixed. The difference in overall mean accuracy between Post-Training$_{\text{New}}$ (49%) and Pre-Training (41%) was statistically significant, corresponding to a 20% improvement. However, the significant Learning Component by Emotion interaction revealed that improvement was restricted to only two emotions: anger and sadness. This trend is also revealed by the pattern of change in confusions across levels of the Learning Component factor (Tables 2-5). Generally, the proportion of confusions tended to decrease with training (Table 3 and 4), but increased again with the introduction of novel drawings in Post-Training$_{\text{New}}$ (Table 5). The notable exception was anger, which was frequently confused with other emotion in Pre-Training, but only with disgust in Post-Training$_{New}$. Therefore, it appears that learning was largely token-specific: participants learned to recognize particular drawings in the training set, and to associate these with the correct emotion label. As previously suggested by McGregor et al. (in press), 2D raised-line drawings may be simply too crude to provide the haptic system with sufficient information to make higher-order classifications (Rosch et al., 1976). Another possibility is that participants did not treat the images as faces *per se*, but rather as abstract line patterns, and therefore never learned to perceive the invariants of each emotion (Lederman et al., 2007). On the other hand, some generalization was observed, albeit limited to two expressions (anger and sadness). Furthermore, the potential for generalization may have been restricted by ceiling effects, given the fact that happiness and surprise were classified very accurately even before participants were given training.

Although not statistically significant, response time was inversely related to classification accuracy: participants took longest to respond in Pre-Training, followed in turn by Post-Training$_{New}$, then Final Training, and finally Post-Training$_{Old}$. That this relationship was non-significant may have been due to the high variability of haptic response times and to the fact that 5% of the trials reached maximum response time (45 s) and were stopped by the experimenter.

A similar overall learning trend was observed in the vision study (Experiment 2). Mean classification accuracy rose significantly from Pre-Training (67%) to Post-Training$_{Old}$ (90%), for a mean percent improvement of 34%. Novel tokens were not classified with significantly greater accuracy in Post-Training$_{New}$ (79%) than in Pre-Training. However, the trend was in the predicted direction and the effect may well prove significant with more participants. Thus, learning tended to be strongly token-specific for vision as well as haptics.

4.4.3 Were some facial expressions easier to classify than others?

Overall, some facial expressions of emotion were haptically identified with higher accuracy than others. Accuracy was highest for happiness and surprise, followed by anger and sadness, and then by disgust (but equivalent with sadness) and fear. Response times mirrored this pattern in that happiness and surprise were identified faster than the other emotions, which were equivalent.

This classification performance order is consistent with earlier studies by Lederman et al. (2008; 2D raised-line drawings), Baron (2008; 3D rigid facemasks), and Lederman et al. (2007; static and dynamic live faces) in that happiness and surprise formed a high-performance sub-group, while fear and disgust fell into a low-performance sub-group. Anger and sadness appeared to be less predictable, as previously found.

A similar pattern was observed when participants performed this task visually. The order of performance for emotions from highest to lowest was: happiness, surprise, and anger, followed by sadness (sadness = surprise, anger), then by disgust and fear. Again, response times were faster for happiness and surprise relative to all other emotions, except anger.

What makes some emotions easier to recognize than others? As previously argued by Lederman et al. (2008) and Lederman et al. (2007), happiness and surprise are easier to classify because they contain distinct mouth geometries (U-shape, and O-shape, respectively), and are more perceptually accessible to the hand. Ho (2006) assessed the relative importance of specific facial features for the classification of 2D raised-line facial expressions of emotion and found that deleting the mouth region contours resulted in greater classification impairment than when the eye + eyebrows contours were deleted. Also, some emotions may be less universally recognizable than others. Elfenbein and Ambady (2002) conducted a meta-analysis to examine visual emotion recognition within and across cultures. They found that happiness was most recognizable cross-culturally, while disgust and fear were least. Further, the in-group advantage observed (i.e. emotion was expressed and perceived by members of the same cultural group) was lowest for fear and disgust, but highest for happiness. It is interesting to speculate that discrepancies in the universal recognizability of primary facial expressions of emotion may apply to haptics, as well as to vision.

4.4.4 What was the effect of training on task performance by blind participants?

The heterogeneity of subject characteristics and the small sample size of this group made statistical analysis inappropriate. Instead, we chose to treat the four participants' data as separate case studies, and to focus rather on trends and differences relative to the large sighted group.

As can be seen in Figure 7, three of the four blind participants (RH, SC, SK) greatly improved from Pre-Training to Post-Training$_{Old}$. Additionally, in Post-Training$_{New}$, the same three participants classified completely novel drawings more accurately than in Pre-Training. Therefore, blind participants showed a learning trend that was similar to that of the sighted. Their improvement from Pre-Training to Post-Training$_{Old}$ suggests underlying token-specific learning. The improvement from Pre-Training to Post-Training$_{New}$ also hints at the possibility of generalization. SK, who was born without any sight, performed with considerably lower accuracy relative to the adventitiously blind and sighted group throughout the study; nevertheless, SK's pattern of learning was similar to that of other participants (sighted and adventitiously blind).

One interesting finding was that for three of four blind participants (RH, SC, and KB), Pre-Training accuracy was higher than for the sighted group. Furthermore, RH and SC continued to classify emotions as well as, if not better than, the sighted group in the subsequent stages of the study (i.e.,Training and Post-Training$_{Old/New}$). This was somewhat surprising because studies such as Galati et al. (2003), and Castanho and Otta (1999) reported that when congenitally blind individuals are asked to generate facial expressions of emotion produced at the experimenter's request, their displays are less recognizable to sighted observers than those produced by sighted encoders. Based on these findings, we reasoned that the ability to now haptically decode facial expressions of emotion might also be linearly related to years of past visual experience. Instead, our results are in line with Heller (1989), who found that when asked to identify raised-line depictions of common objects, the adventitiously blind outperform both sighted and congenitally blind individuals. He attributed this finding to the fact that individuals who lost their sight later in life have had greater prior exposure to pictures than the congenitally blind, and are generally more experienced using their sense of touch than the sighted. Indeed, in a brief questionnaire implemented after the study was completed, all of our blind participants indicated that they had had some, albeit limited, previous experience with tangible displays, such as 2D raised-line mathematical charts and graphs, or 3D tangible maps of the world. Their greater tactual skills probably also accounts for their relatively fast response times (Figure 8).

In conclusion, although limited data for this group make it difficult to interpret their results conclusively, it appears that blind individuals can be trained to haptically identify 2D raised-line drawings depicting the six culturally universal facial expressions of emotion. Furthermore, our results support the notion that although past visual experience likely facilitates haptic processing of 2D raised-line pictures, it is not necessary for their perception (Heller, 1989).

4.4.5 Section summary

Training participants to classify the six primary facial expressions of emotion in 2D raised line drawings significantly improved performance accuracy both haptically (Experiments 1 and 3) and visually (Experiment 2). Mean classification accuracy appeared to be highest for the group that performed the task visually, followed by the adventitiously blind, then the sighted (blindfolded), and finally, by our congenitally blind participant. However, the learning trend was very similar for all participant groups. Learning was mostly token-specific, with generalization limited to anger and sadness in the haptic study. Generalization may have been limited by ceiling effects reflected by the generally high classification accuracy for most of the emotions in the vision study (Experiment 2) and happiness and surprise in the haptic study (Experiment 1).

Chapter 5.0 Limitations, future directions, and applications

5.1 Limitations

There were several limitations to this study. First, it would have been preferable to present each token more frequently in each of the four Learning Components in order to render the data distribution more continuous. However, time constraints and the need to increase the potential for learning made it necessary to exclude repetitions in order to maximize the number of training trials.

Second, only four Caucasian, female actors portrayed the facial expressions of emotion in our displays. Ideally, a greater number of models ranging in race, age, and gender would have been included to increase the generality of our findings. However, as explained immediately above, this was not possible because it would have required a greater number of trials in an already lengthy experimental session.

Third, our displays were stereotyped and extreme versions of each facial expression of emotion, loosely based on those photographed by Ekman and colleagues (e.g., Ekman & Friesen, 1975). Until very recently much of the research on visual face perception has used similarly intense displays of emotion. However, outside the laboratory facial affect is not restricted to such extreme and stereotyped displays. It would be interesting to perform a haptic face processing study assessing the ability of sighted, blindfolded individuals to classify facial expressions of emotion using more subtle or non-stereotyped expressions of each emotion. For example, completely untrained actors could be asked to produce their version of different facial expressions of emotion, while another untrained group of sighted, blindfolded observers would be required to haptically classify these subjective displays. Assuming that the exaggerated facial expressions of emotion such as those used in previous studies (e.g. Lederman et al., 2007) provide more haptically accessible cues than more subtle versions, we might expect the latter to be classified with lower accuracy.

Fourth, in our learning paradigm, the Post-Training consisted of Post-$\text{Training}_{\text{Old}}$ and Post-$\text{Training}_{\text{New}}$ components, where drawings belonging to the training set were combined with novel drawings and randomly presented. This manipulation was carried out to minimize the possibility that participants might adopt a response strategy based on a process of elimination, given that during each Learning Component the drawings in the set were presented only once without replacement. A potential limitation here is that the unannounced introduction of a new set of drawings may have introduced some confusion for participants, resulting in lowered classification accuracy for the Old set drawings. Fortunately, such effects would appear to have been relatively negligible because accuracy did not decrease significantly from Final Training to Post-$\text{Training}_{\text{Old}}$.

Finally, recruitment of blind participants proved to be exceptionally challenging, accounting for the small size of our blind participant group and making statistical evaluation of their results unfeasible. Furthermore, there were too few data points to precisely determine whether relative emotions were classified similarly to those of the sighted, or even to each other.

5.2. Future directions

Several important topics would seem to merit future investigation. One direction for future research would involve formal analysis of the effect of past visual experience on the ability to haptically classify facial expressions of emotion. This direction would involve recruiting a larger number of early and late blind participants and comparing their results with the sighted. Our very preliminary results tentatively suggest that restricted visual experience reduces the ability to classify facial expressions of emotion when vision is lost early in life (e.g. SK), but not when the loss of vision is adventitious (e.g. RH and SC). Two-dimensional raised-line drawings were employed in the present study because we knew from previous work (e.g. Lederman et al., 2008) that these were challenging stimuli for haptic perception, and that they would help minimize possible ceiling effects. They were also appropriate stimuli for a study that specifically aimed to assess the effect of training a large group of sighted participants to classify facial expressions of emotion that permitted much room for learning. However, in a study looking at the effect of visual experience, live faces or 3D facemasks may be more suitable stimuli because they are richer in haptically salient cues.

Second, the role of visual imaging during haptic object processing is another interesting but highly controversial topic in haptic research that merits further investigation. For example, when Lederman et al. (1990) required participants to identify common objects depicted in 2D raised-line drawings, objects that were reportedly easiest to image were classified with the highest accuracy. Furthermore, the authors found a significant negative correlation between scores on the Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973) and recognition accuracy, where a lower VVIQ indicates stronger imaging ability. These correlations suggested that haptic exploration of 2D raised-line drawings requires the use of visual processing channels. On the other hand, no such correlation was reported when Kilgour and Lederman (2002) used live faces and 3D facemasks in a match-to-sample face identification task, suggesting that with such displays image-mediation was not necessary for good performance. It would be interesting to determine whether this connection also applies to haptic classification of facial expressions of emotion in 2D vs. 3D displays. We might expect that emotions that are easiest to image would be classified with highest accuracy, at least when displayed in 2D raise-line drawings, which are believed to involve the use of visual mediation.

Third, in addition to assessing whether visual channels mediate haptic processing, it would also be interesting to investigate whether visually acquired representations of facial expressions of emotion can be accessed by haptic processing, and vice versa (i.e., whether cross-modal transfer occurs with respect to facial expressions of emotion). To this author's knowledge, no studies have yet assessed the potential of cross-modal transfer for facial expressions of emotion. Instead, several studies have examined the existence of cross-modal transfer for recognition of facial identity. Kilgour and Lederman (2002) found that when participants explored a standard face visually, they were slightly more accurate recognizing it when subsequently asked to examine comparison faces haptically. This was also true when the standard face was presented haptically and matched visually, albeit to a lesser extent. Also, Casey and Newell (2005) demonstrated that cross-modal transfer is greater for newly familiar faces than unfamiliar faces, with respect to facial identity. Given previous findings that facial expressions of emotion are more haptically accessible than facial identity (McGregor et al., in press), we might predict greater cross-modal transfer for the former.

Fourth, it would be interesting to investigate whether further training would eventually result in a more pronounced shift in learning from token-specific learning to generalization. This would clearly require a longer-term study using a similar hybrid learning paradigm. Participants would be trained over a more extended number of sessions, which in turn would offer the opportunity to include both a greater number of actors and more repetitions of each drawing. In the current study, happiness and surprise were classified very accurately even prior to training, suggesting that ceiling effects may limit the potential for further improvement or generalization. However, it is possible that classification accuracy for novel versions of sadness, anger, fear, and disgust may improve with further training.

5.3 Applications

Several studies suggest that congenitally blind individuals have more trouble voluntarily expressing facial affect than the sighted (e.g. Castanho, & Otta, 1999; Galati et al., 2003). This deficit is attributed to their minimal exposure to and lack of feedback about facial expressions of emotion, which normally occurs via the visual modality (Galati et al., 1997). Given the finding that facial expressions of emotion contain cues that are also accessible to the hand (e.g. Lederman et al., 2007), haptics may provide an effective way for blind individuals to learn about this form of social communication. Ideally, blind children could be encouraged to learn about the deliberate production of facial expressions of emotion by manually exploring their parents’ faces as well as their own. However, it is often neither possible nor appropriate to learn about facial expressions of emotion by feeling a live face. Our findings tentatively suggest that congenitally blind individuals can be trained to process facial expressions of emotion depicted in simple 2D raised-line drawings. The benefit of using this type of stimulus is that it is relatively easy and inexpensive to produce. Three-dimensional facemasks are another potential option. Although they are more difficult to produce, 3D facemasks contain a wealth of haptically accessible information about the musculoskeletal configurations involved in facial expressions of emotion.

Furthermore, haptic face stimuli have potential as teaching aids for blind students when learning about facial expressions of emotion (e.g. in Psychology classes). Two-dimensional raised-line drawings are very portable and could be used to compliment discussions about facial expressions of emotion in classroom settings.

Finally, both 2D raised-line drawings and 3D facemasks are excellent for future investigations of the neural processes that underlie haptic facial perception, as they can readily be used in fMRI machines.

To conclude, given the finding that haptic processing is a bimodal perceptual phenomenon (Kilgour & Lederman, 2002), learning about facial expressions of emotion by manually exploring haptically informative facial displays may offer a viable channel for this type of social communication when pattern vision is not available.

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Appendix A: Experiment 1- Haptic study with sighted, blindfolded participants

The Effect of Training on the Recognition of Facial Expressions of Emotion by Touch

Letter of Information

Hello, my name is Aneta Abramowicz, and I invite you to participate in a research project for my Master's in Neuroscience Degree. This project is supervised by Dr. Susan Lederman at Queen's University in Kingston, Ontario. Dr. Lederman is the researcher who, with the cooperation of the CNIB and the Bank of Canada, designed the raised tactile feature and tactile codes that appear on the new Canadian banknotes. My research proposal has been approved by the General Research Ethics Board at Queen's University and has also received Ethics approval from the CNIB.

My goal is to find out if people with varying levels of visual impairment can use their sense of touch alone to learn to recognize different facial expressions of emotion in raised outline drawings. If you choose to participate, I will ask you to wear a blindfold and headphones and to manually explore raised outline drawings that portray six different culturally universal facial expressions of emotion. Your task will be to tell me which expression of emotion you believe you are feeling and to learn about how these different expressions feel to touch. During some parts of the experiment, I will train you to identify the six expressions of emotion by first naming the expression that you are about to feel or by giving you feedback once you've given me your response. At other times, I will give you no feedback after you have responded.

The entire study will take about 1.5 hours, for which you will be paid $10/hr.

By choosing to participate in this study, you will help us learn more about how facial expressions of emotion can be recognized by hand rather than by eye. We hope your participation will help us determine if persons with notable visual impairments can use such tactile graphics displays as one of several possible future avenues for enhancing social communication.

There are no known physical, psychological, social, or economic discomforts or inconveniences associated with this project. Your participation is completely voluntary and you are free to withdraw from the study at any time.

Thank you!

Aneta Abramowicz

The Effect of Training on the Recognition of Facial Expressions of Emotion by Touch

Consent Form

Name: ____

1. I have read the Letter of Information and have had any questions answered to my satisfaction.

2. I understand that I will be participating in a study called The Effect of Training on the Recognition of Facial Expressions of Emotion by Hand. I understand that I will be asked to wear a blindfold and a pair of headphones to block out any sound cues during the study. Next, I will be asked to use my hands to explore raised line drawings displaying different facial expressions of emotion, and to then identify which emotion the drawing portrays. I understand that I will be given training during some parts of the study. My answers will be written down throughout the experiment and entered into a computer file. I understand that this session will last about 1.5 hrs.

3. I understand that my participation in this study is voluntary and that I may withdraw at any time. If I choose to withdraw from the experiment prior to its completion, I will still be compensated and the data collected to that point will be destroyed.

4. I understand that there are no known physical, psychological, social, or economic discomforts or inconveniences associated with this project.

5. I understand that every effort will be made to maintain the confidentiality of the data now and in the future. If I am asked to have my hands videotaped, my identity will not be evident in the videotape, which will be stored along with other data from my participation in a locked laboratory to which only members of Dr. Lederman's lab have access. Computer entered data will be kept in a password protected file.

6. I am aware that if I have any concerns, or complaints, there are several people I may contact: my supervisor, Dr. Susan Lederman (613-533-2878, susan.lederman@queensu.ca), the Coordinator of Neuroscience Graduate Studies, Dr. James Reynolds (613-533-6946, jnr@queensu.ca), or the Chair of the General Research Ethics Board at Queen's University, Dr. Steve Leighton (613-533-6081, chair.GREB@queensu.ca).

I have been read the above statements and freely consent to participate in this research:

Signature: ______________________________________

Date: _________________________

Instructions: Overview

In this study, you will be trained to identify six facial expressions of emotion made by a number of different actors using only your hands. You will do this by manually exploring raised line drawings depicting these facial expressions. You will be asked to wear a blindfold and headphones to block out extra visual and auditory cues. (We ask that all participants wear these in order to guarantee that the results are scientifically acceptable).

There are three types of trials in this study and you will experience each type several times as the study progresses. I will tell you when we are about to begin a new trial type and I will give you the instructions for that type before we start.

The three types of trials are:

1) **Trials where you will be asked to identify which of the six facial expressions of emotion you think you are exploring and where <u>I will not say anything once you have responded.</u> We will immediately move on to the next trial.**

2) **Trials where you will be asked to identify which of the six facial expressions of emotion you think you are exploring and where <u>I will tell you what expression you had been feeling once you have responded</u>.**

3) **Trials <u>where you will not be asked to identify a facial expression</u> because I will have told you the expression you are about to feel prior to the start of the trial**.

I will also sometimes pause the study to take a confidence measure. I will ask you to rate how confident you felt while you identified each of the six facial expressions. You will be asked to use a scale from 1-7 where 1 corresponds to “not confident at all” and 7 is “extremely confident”. Please feel free to use decimal numbers.

Any questions before I now give you instructions about the first type of trials in the study?

Instructions: Part I

We will begin with trials where you will be asked to identify which of the six facial expressions of emotion you think you are exploring and where I will NOT give you feedback after you respond.

Your task: To identify which facial expression of emotion you are exploring as quickly and accurately as you can.

Before the start of these trials, you will sit with your hands resting on a table. When I say "Ready, start", please start exploring the drawing that I will have placed directly in front of you. As soon as you think you know what the emotion is, I want you to remove your hands from the drawing and tell me your choice. Please choose your response from the list of expressions that I will go through with you before we begin. Be as fast and as accurate as you can. If you are not sure, please give your best guess. You can explore the drawing however you like for up to 45 seconds. If you haven't responded after 45 seconds, I will stop you and ask for your response. Once you've responded, I will not say anything and we will immediately move on to the next trial.

Now I will name the six possible expressions that you will feel:

Anger Disgust Fear Happiness Sadness Surprise

Because this is the list that you should choose your answer from, it is important that you remember these six emotions. So I will periodically pause the trials and ask you to recite the list back to me. Also, if at any point you find that you are having difficulty remembering these emotions, please let me know and I will repeat them again. Can you remember them now?

Keep in mind that you will be presented with repetitions of each emotion and because these will be presented in no particular order, it is possible that the same expression may appear back-to-back.

Before we begin, I will first give you some time to practice this task using a drawing that portrays a neutral expression. Any questions before we start?

Instructions: Part II

Now we will go through some trials where you will not be asked to respond because I will have told you what expression you are about to explore.

Your task: To learn what each facial expression "feels" like to touch.

Before the start of these trials, I will name the expression that you are about to explore. For example, before the start of the trial I might say: "This is anger". Then, when I say "Ready, start", please immediately start exploring the drawing, paying close attention to what it feels like. As with the other trials in the study, you can explore the drawing however you like for up to 45 seconds. When you feel that you done exploring the drawing and are ready to move on to the next trial, please remove your hands and I will identify the next expression that you will be exploring.

Any questions before I name the first expression you will be exploring?

Instructions: Part III

The next type of trial coming up is the one where you will be asked to identify which of the six facial expressions of emotion you think you are exploring and where I will tell you what expression you had been feeling once you have responded.

Your task: To identify which facial expression of emotion you are exploring as quickly and accurately as you can.

These trials are identical to the ones where you responded but were not given feedback, but now rather than being silent after you have responded, I will name the expression to you before moving on to the next trial. As before, you will have up to 45 seconds to respond.

Remember that you can choose your answer from the following list of emotions:

Anger Disgust Fear Happiness Sadness Surprise

Any questions before we begin these trials with feedback?

Edinburgh Handedness Inventory

Please indicate your preferences in the use of hands in the following activities by putting a check in the appropriate column. Where the preference is so strong that you would never try to use the other hand, unless absolutely forced to, put 2 checks. If in any case you are really indifferent put a check in both columns.

Some of the activities listed below require the use of both hands. In these cases the part of the task, or object, for which hand preference is wanted is indicated in brackets.

Please try and answer all of the questions, and only leave a blank if you have no experience at all with the object or task.

	Left	Right
1. Writing	☐ ☐	☐ ☐
2. Drawing	☐ ☐	☐ ☐
3. Throwing	☐ ☐	☐ ☐
4. Scissors	☐ ☐	☐ ☐
5. Toothbrush	☐ ☐	☐ ☐
6. Knife (without fork)	☐ ☐	☐ ☐
7. Spoon	☐ ☐	☐ ☐
8. Broom (upper hand)	☐ ☐	☐ ☐
9. Striking Match (match)	☐ ☐	☐ ☐
10. Opening box (lid)	☐ ☐	☐ ☐
TOTAL(count X's in both columns)		

Scoring:
Add up the checks in both left and right columns.
Whichever number is greater, would be considered your handedness.

The Effect of Training on the Recognition of Facial Expressions of Emotion by Touch

Questionnaire

1. How often did you pay attention to the whole face when you were feeling the drawings?

   not at all   not very often   some of the time   quite often   all the time

2. Which facial feature or features did you find especially informative? If specific to an emotion, then please say so.

____

____

____

____

____

____

3. Did you feel like you were getting better at identifying the expressions as you went along?

4.
   a) **If so**, what helped you learn about the expressions? Do you feel like you changed the way that you performed the task from beginning to end (e.g. did you use different strategies or cues)?
   b) **If not**, can you think of anything that would have been made this task easier?

____

____

____

____

____

____

5. Did you find yourself mimicking some or all of the expressions that you were feeling? If you only mimicked certain expressions, which were they?

____

____

The Effect of Training on the Recognition of Facial Expressions of Emotion by Touch

Debriefing

Thank you very much for participating in my research project! The purpose of this study was to examine whether people are capable of learning to identify facial expressions of emotion using their sense of touch alone. Previous research has shown that it is possible to recognize the same 6 expressions you have experienced without training, however, accuracy was not very high. In the current study, we now ask whether performance can improve with training, and if so, what type of learning has occurred. We are also interested in determining whether persons with notable visual impairments can use such tactile graphic displays as one of several possible future avenues for enhancing social communication.

Because we are still running this study, we would appreciate your not discussing this experiment with anyone else in order to avoid producing biased results. If you are interested in receiving the results of this study once it is completed, please feel free to contact Dr. Lederman's lab at clh@post.queensu.ca or Dr. Susan Lederman at lederman@post.queensu.ca.

If you have any concerns or complaints about this study, please feel free to contact my supervisor, Dr. Susan Lederman (613-533-2878, susan.lederman@queensu.ca), the Coordinator of Neuroscience Graduate Studies, Dr. James Reynolds (613-533-6946, jnr@queensu.ca), or the Chair of the General Research Ethics Board at Queen's University, Dr. Steve Leighton (613-533-6081, chair.GREB@queensu.ca).

Thanks very much again for participating in this research project!

Appendix B: Experiment 2- Vision control study

The Effect of Training on the Recognition of Facial Expressions of Emotion

Letter of Information

Hello, my name is Aneta Abramowicz, and I invite you to participate in a research project for my Master's in Neuroscience Degree. This project is supervised by Dr. Susan Lederman at Queen's University in Kingston, Ontario. My research proposal has been approved by the General Research Ethics Board at Queen's University and has also received Ethics approval from the CNIB.

My goal is to determine how well people can learn to visually recognize facial expressions of emotion when only the outline of the facial features is visible. If you choose to participate, I will ask you to wear a special pair of goggles that will block your vision in between trials, as well as a pair of headphones. You will then be asked to look at outline drawings that portray six different culturally universal facial expressions of emotion. Your task will be to tell me which expression of emotion you believe you are looking at. During some parts of the study, I will train you to identify the six expressions of emotion by either first naming the expression that you are about to look at or by giving you feedback once you've given me your response. At other times, I will give you no feedback after you have responded.

The entire study will take about 1 hour, for which you will be paid $10 or receive 1.0 credits towards PSYC 100.

By choosing to participate in this study, you will help us learn more about how training affects the visual recognition of facial expressions of emotion in outline drawings.

There are no known physical, psychological, social, or economic discomforts or inconveniences associated with this project. Your participation is completely voluntary and you are free to withdraw from the study at any time.

Thank you!

Aneta Abramowicz

The Effect of Training on the Recognition of Facial Expressions of Emotion

Consent Form

Name: ____

1. I have read the Letter of Information and have had any questions answered to my satisfaction.

2. I understand that I will be participating in a study called The Effect of Training on the Recognition of Facial Expressions of Emotion. I understand that I will be asked to wear goggles and a pair of headphones during the study. Next, I will be asked to look at outline drawings displaying different facial expressions of emotion, and to then identify which emotion the drawing portrays. I understand that I will be given training during some parts of the study. My answers will be written down throughout the experiment and entered into a computer file. I understand that this session will last about 1 hour.

3. I understand that my participation in this study is voluntary and that I may withdraw at any time. If I choose to withdraw from the experiment prior to its completion, I will still be compensated and the data collected to that point will be destroyed.

4. I understand that there are no known physical, psychological, social, or economic discomforts or inconveniences associated with this project.

5. I understand that every effort will be made to maintain the confidentiality of the data now and in the future. Data from my participation will be kept in a locked laboratory to which only members of Dr. Lederman's lab have access. Computer entered data will be kept in a password protected file.

6. I am aware that if I have any concerns, or complaints, there are several people I may contact: my supervisor, Dr. Susan Lederman (613-533-2878, susan.lederman@queensu.ca), the Coordinator of Neuroscience Graduate Studies, Dr. Stephen Scott (613-533-6946, steve@biomed.queensu.ca), or the Chair of the General Research Ethics Board at Queen's University, Dr. Steve Leighton (613-533-6081, chair.GREB@queensu.ca).

I have been read the above statements and freely consent to participate in this research:

Signature: _____________________________________

Date: _______________________

Instructions: Overview

In this study, you will be trained to visually identify six facial expressions of emotion made by a number of different actors. You will be asked to wear a pair of goggles and headphones (We ask that all participants wear these in order to guarantee that the results are scientifically acceptable).

There are three types of trials in this study and you will experience each type several times as the study progresses. I will tell you when we are about to begin a new trial type and I will give you the instructions for that type before we start.

The three types of trials are:

4) **Trials in which you will be asked to identify which of the six facial expressions of emotion is being portrayed and where <u>I will not say anything once you have responded.</u> We will immediately move on to the next trial.**

5) **Trials <u>in which you will not be asked to identify a facial expression</u> because I will have told you the expression you are about to see prior to the start of the trial**.

6) **Trials in which you will be asked to identify which of the six facial expressions of emotion is being portrayed and where <u>I will tell you what expression you had been looking at once you have responded</u>.**

I will also sometimes pause the study to take a confidence measure. I will ask you to rate how confident you felt while you identified each of the six facial expressions. You will be asked to use a scale from 1-7 where 1 corresponds to “not confident at all” and 7 is “extremely confident”. Please feel free to use decimal numbers.

Any questions before I now give you instructions about the first type of trials in the study?

Instructions: Part I

We will begin with trials in which you will be asked to identify which of the six facial expressions of emotion you think you are looking at and where I will NOT give you feedback after you respond.

Your task: To identify which facial expression of emotion you are looking at as quickly and accurately as you can.

Before the start of these trials, you will be wearing a pair of goggles that will prevent you from seeing anything. Immediately after I say "Ready, start", the goggles will become transparent and you will be able to see the outline drawing of facial expression of emotion that I will have placed on the clipboard directly in front of you. Please say the name of the expression of emotion out loud as soon as you think you know it. The goggles will become opaque again as soon as you respond. You can look at the drawing for up to 45 seconds. If you haven't responded after 45 seconds, the goggles will become opaque and I will ask for your response or best guess. Once you have responded, I will not say anything and we will immediately move on to the next trial.

The six possible expressions that you will see are:

Anger Disgust Fear Happiness Sadness Surprise

Because this is the list that you should choose your answer from, it is important that you remember these six emotions. So I will periodically pause the trials and ask you to recite the list back to me. Also, if at any point you find that you are having difficulty remembering these emotions, please let me know and I will repeat them again. Can you remember them now?

Keep in mind that you will be presented with repetitions of each emotion and because these will be presented in no particular order, it is possible that the same expression may appear back-to-back.

Before we begin, I will first give you some time to practice this task using a drawing that portrays a neutral expression. Any questions before we start?

Instructions: Part II

Now we will go through some trials in which you will not be asked to respond because I will have told you what expression you are about to look at.

Your task: To learn what the outline of each facial expression looks like.

Before the start of these trials, I will name the expression that you are about to look at. For example, before the start of the trial I might say: “This is anger”. Then, when I say “Ready, start”, the goggles will become transparent and you will be able to see the drawing in front of you. As with the other trials in this study, you will have up to 45 seconds to look at the drawing. When you feel that you are done looking at the drawing and are ready to move on to the next trial, please say “OK” or “done” and I will turn the goggles opaque. I will then identify the next expression that you are about to look at.

Any questions before I name the first expression that you will look at?

Instructions: Part III

The next type of trial coming up is the one in which you will be asked to identify which of the six facial expressions of emotion you think you are looking at and where I will tell you what expression was being shown after you have responded.

Your task: To identify which facial expression of emotion you are looking at as quickly and accurately as you can.

These trials are identical to the ones where you responded and were not given feedback, but now I will name the expression to you once you've given me your response. As before, you will have up to 45 seconds to respond.

Remember that you can choose your answer from the following list of emotions:

Anger Disgust Fear Happiness Sadness Surprise

Any questions before we begin these trials with feedback?

The Effect of Training on the Recognition of Facial Expressions of Emotion

Questionnaire

1. How often did you pay attention to the whole face when looking at the drawing?

   not at all   not very often   some of the time   quite often   all the time

2. Which facial feature or features did you find especially informative? If specific to an emotion, then please say so.

3. Did you feel like you were getting better at identifying the expressions as you went along?
   - c) **If so**, what helped you learn about the expressions? Do you feel like you changed the way that you performed the task from beginning to end (e.g. did you use different strategies or cues)?
   - d) **If not**, can you think of anything that would have been made this task easier?

6. Did you find yourself mimicking some or all of the expressions that you saw? If you only mimicked certain expressions, which were they?

The Effect of Training on the Recognition of Facial Expressions of Emotion

Debriefing

Thank you very much for participating in my research project! Facial expressions of emotion are a group of common objects that are traditionally found in our visual environment. However, previous research using blindfolded participants shows that it is also possible to recognize the same 6 expressions that you have experienced using the sense of touch alone. The main purpose of my study is to determine the effect of training on the recognition of facial expressions by touch. Participants in both the ‘vision’ and ‘touch’ versions of the study experienced the same drawings of facial expressions that you have just experienced, only that the drawings you looked at in this visual version of the study were made into 2D raised line drawings for the ‘touch’ version. I plan on comparing the results from the visual study that you were part of with the results from the tactual version of the same study.

Because we are still running this study, we would appreciate your not discussing this experiment with anyone else in order to avoid producing biased results. If you are interested in receiving the results of this study once it is completed, please feel free to contact Dr. Lederman’s lab at clh@post.queensu.ca or Dr. Susan Lederman at lederman@.queensu.ca.

If you have any concerns or complaints about this study, please feel free to contact my supervisor, Dr. Susan Lederman (613-533-2878, susan.lederman@queensu.ca), the Coordinator of Neuroscience Graduate Studies, Dr. Stephen Scott (613-533-6946, steve@biomed.queensu.ca), or the Chair of the General Research Ethics Board at Queen’s University, Dr. Steve Leighton (613-533-6081, chair.GREB@queensu.ca).

Thanks very much again for participating in this research project!

Appendix C: Experiment 3- Haptic case studies with blind participants

The Effect of Learning on the Recognition of Facial Expressions of Emotion by Touch

Letter of Information

Hello, my name is Aneta Abramowicz, and I invite you to participate in my Master's Thesis project. This project is supervised by Dr. Susan Lederman at Queen's University in Kingston, Ontario. Dr. Lederman is the researcher who, with the cooperation of CNIB and the Bank of Canada, designed the raised tactile feature and tactile code that appears on the new Canadian banknotes. My research proposal has been approved by the General Research Ethics Board at Queen's University and has also received Ethics approval from the CNIB.

My objective is to determine whether people with varying visual abilities can learn to successfully recognize facial expressions of emotion using only their hands. If you choose to participate, I will first assess the sensitivity of your hands using several standard measures. I will then ask you to feel two-dimensional raised-line drawings that display different culturally universal facial expressions of emotion. Your task will be to tell me which expression you believe that you are feeling. I will sometimes tell you what emotion the drawing was displaying once you have given me your response.

The entire study will take about 2.5 hours, for which you will be paid $50. You will also be paid an extra $30 to help cover your transportation cost to and from Queen's University (Humphrey Hall).

By choosing to participate in this study, you will help us learn more about the capabilities of the sense of touch and about the possibility of using touch as a channel for learning about facial expressions of emotion.

There are no known physical, psychological, social, or economic discomforts or inconveniences associated with this project. Your participation is completely voluntary and you are free to withdraw from the study at any time.

All measures will be taken to ensure that only the people directly involved with the project will have access to the data collected and that your name will not be linked to the results.

If you are interested in participating in this study, please call: (613) 484-8572 or email abraneta@gmail.com.

Sincerely,

Aneta Abramowicz

The Effect of Training on the Recognition of Facial Expressions of Emotion by Touch

Consent Form

Name: ____

I will now read the experimental consent form to you out loud. Please state "yes", indicating that you give your consent following each statement, or state "no", or that you do not give your consent to one or more of the following statements:

1. I have read the Letter of Information and have had any questions answered to my satisfaction.

2. I understand that I will be participating in a study called The Effect of Training on the Recognition of Facial Expressions of Emotion by Hand. I understand I will initially have my tactile sensitivity assessed with standard measures and that I will be asked to wear a pair of goggles and headphones to block out any visual and sound cues during the main experiment. Next I will be asked to use my hands to explore 2D raised line drawings displaying different facial expressions of emotion, and to then classify which emotion the drawing portrays. I understand that I will be given feedback after I have given my answer during the training portion of the experiment. My answers will be written down throughout the experiment and entered into a computer file. I will also be asked to answer a short questionnaire at the end of the experiment. I understand that this session will last about 2.5 hrs.

3. I understand that my participation in this study is voluntary and that I may withdraw at any time. If I choose to withdraw from the experiment prior to its completion, I will still be compensated and the data collected to that point will be destroyed.

4. I understand that there are no known physical, psychological, social, or economic discomforts or inconveniences associated with this project.

5. I understand that every effort will be made to maintain the confidentiality of the data now and in the future. If I am asked to have my hands videotaped, my identity will not be evident in the videotape, which will be stored along with other data from my participation in a locked laboratory to which only members of Dr. Lederman's lab have access. Computer entered data will be kept in a password protected file.

6. I am aware that if I have any concerns, or complaints, there are several people I may contact: my supervisor, Dr. Susan Lederman (613-533-2878, susan.lederman@queensu.ca), the Coordinator of Neuroscience Graduate Studies, Dr. James Reynolds (613-533-6946, jnr@queensu.ca), or the Chair of the General Research Ethics Board at Queen's University, Dr. Steve Leighton (613-533-6081, chair.GREB@queensu.ca).

I have been read the above statements and freely consent to participate in this research:

Signature: ______________________________________

Date: ________________________

Instructions: Overview

In this study, you will be trained to identify six facial expressions of emotion made by a number of different actors using only your hands. You will do this by manually exploring raised line drawings depicting these facial expressions.

There are three types of trials in this study and you will experience each type several times as the study progresses. I will tell you when we are about to begin a new trial type and I will give you the instructions for that type before we start.

The three types of trials are:

1) **Trials where you will be asked to identify which of the six facial expressions of emotion you think you are exploring and where I will not say anything once you have responded. We will immediately move on to the next trial.**

2) **Trials where you will be asked to identify which of the six facial expressions of emotion you think you are exploring and where I will tell you what expression you had been feeling once you have responded.**

3) **Trials where you will not be asked to identify a facial expression because I will have told you the expression you are about to feel prior to the start of the trial**.

I will also sometimes pause the study to take a confidence measure. I will ask you to rate how confident you felt while you identified each of the six facial expressions. You will be asked to use a scale from 1-7 where 1 corresponds to “not confident at all” and 7 is “extremely confident”. Please feel free to use decimal numbers.

Any questions before I now give you instructions about the first type of trials in the study?

Instructions: Part I

We will begin with trials where you will be asked to identify which of the six facial expressions of emotion you think you are exploring and where I will NOT give you feedback after you respond.

Your task: To identify which facial expression of emotion you are exploring as quickly and accurately as you can.

Before the start of these trials, you will sit with your hands resting on a table. When I say “Ready, start”, please start exploring the drawing that I will have placed directly in front of you. As soon as you think you know what the emotion is, I want you to remove your hands from the drawing and tell me your choice. Please choose your response from the list of expressions that I will go through with you before we begin. Be as fast and as accurate as you can. If you are not sure, please give your best guess. You can explore the drawing however you like for up to 45 seconds. If you haven’t responded after 45 seconds, I will stop you and ask for your response. Once you’ve responded, I will not say anything and we will immediately move on to the next trial.

Now I will name the six possible expressions that you will feel:

Anger Disgust Fear Happiness Sadness Surprise

Because this is the list that you should choose your answer from, it is important that you remember these six emotions. So I will periodically pause the trials and ask you to recite the list back to me. Also, if at any point you find that you are having difficulty remembering these emotions, please let me know and I will repeat them again. Can you remember them now?

Keep in mind that you will be presented with repetitions of each emotion and because these will be presented in no particular order, it is possible that the same expression may appear back-to-back.

Before we begin, I will first give you some time to practice this task using a drawing that portrays a neutral expression. Any questions before we start?

Instructions: Part II

Now we will go through some trials where you will not be asked to respond because I will have told you what expression you are about to explore.

Your task: To learn what each facial expression “feels” like to touch.

Before the start of these trials, I will name the expression that you are about to explore. For example, before the start of the trial I might say: “This is anger”. Then, when I say “Ready, start”, please immediately start exploring the drawing, paying close attention to what it feels like. As with the other trials in the study, you can explore the drawing however you like for up to 45 seconds. When you feel that you done exploring the drawing and are ready to move on to the next trial, please remove your hands and I will identify the next expression that you will be exploring.

Any questions before I name the first expression you will be exploring?

Instructions: Part III

The next type of trial coming up is the one where you will be asked to identify which of the six facial expressions of emotion you think you are exploring and where <u>I will tell you what expression you had been feeling once you have responded</u>.

Your task: To identify which facial expression of emotion you are exploring <u>as quickly and accurately as you can</u>.

These trials are identical to the ones where you responded but were not given feedback, but now rather than being silent after you have responded, I will name the expression to you before moving on to the next trial. As before, you will have up to 45 seconds to respond.

Remember that you can choose your answer from the following list of emotions:

Anger Disgust Fear Happiness Sadness Surprise

Any questions before we begin these trials with feedback?

Edinburgh Handedness Inventory (Modified)

Please tell me your preferences in the use of hands in the following activities by saying “left” or “right” Please tell me whether the preference is so strong that you would never try to use the other hand, unless absolutely forced to. Please also tell me if in any case you are really indifferent.

Please try and answer all of the questions, and tell me if you have no experience at all with the object or task.

	Left	Right
1. Writing	☐ ☐	☐ ☐
2. Throwing	☐ ☐	☐ ☐
3. Scissors	☐ ☐	☐ ☐
4. Toothbrush	☐ ☐	☐ ☐
5. Knife (without fork)	☐ ☐	☐ ☐
6. Spoon	☐ ☐	☐ ☐
7. Broom (upper hand)	☐ ☐	☐ ☐
8. Opening box (lid)	☐ ☐	☐ ☐
TOTAL(count X’s in both columns)		

Scoring:
Add up the checks in both left and right columns.
Whichever number is greater, would be considered your handedness.

The Effect of Training on the Recognition of Facial Expressions of Emotion by Touch

Questionnaire

1. How often did you pay attention to the whole face when you were feeling the drawings?

   not at all   not very often   some of the time   quite often   all the time

2. Which facial feature or features did you find especially informative? If specific to an emotion, then please say so.

___

___

___

___

___

Did you feel like you were getting better at identifying the expressions as you went along?

a) **If so**, what helped you learn about the expressions? Do you feel like you changed the way that you performed the task from beginning to end (e.g. did you use different strategies or cues)?
b) **If not**, can you think of anything that would have been made this task easier?

___

___

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___

4. Did you find yourself mimicking some or all of the expressions that you were feeling? If you only mimicked certain expressions, which were they?

___

___

5. Have you previously been encouraged to explore someone’s face with your hands? If so, please elaborate on the circumstances.

____

____

____

____

6. Has anyone ever commented on your facial expressions of emotions? If so, what did they say?

____

____

____

7. In your daily interactions with people, what kinds of information do you normally rely on to tell you the emotion a person is expressing?

____

____

____

The Effect of Training on the Recognition of Facial Expressions of Emotion

Debriefing

Thank you very much for participating in my research project! Facial expressions of emotion are a group of common objects that are traditionally found in our visual environment. Previous research using sighted but blindfolded participants has shown that it is also possible to recognize the same 6 expressions that you have experienced using the sense of touch alone, but that accuracy was not very high. The main purpose of the current study is to determine the effect of training on the ability of people with varying degrees of visual ability to recognize facial expressions by touch alone.

Because we are still running this study, we would appreciate your not discussing this experiment with anyone else in order to avoid producing biased results. I will send you the contact information for my supervisor, and lab in case you are interested in receiving the results of this study once it is completed. I will also send you the contact information for individuals that would be able to help you if you have any concerns or complaints about this study.

Thanks very much again for participating in this research project!