Haptic touch and hand ability

Miriam Ittyerah
Department of Psychology
Christ University
Bangalore- 560029, India.

Several studies have compared visual perception, tactile (haptic) perception, and visual-haptic perception of stimuli. Often, performance in tasks involving unimodal visual perception exceeds performance in both unimodal haptic and cross-modal tasks. However unimodal haptic comparisons of natural three-dimensional shapes could be as good as visual-haptic and haptic-visual comparisons. Therefore vision and touch may have functionally overlapping, though not equivalent, representations of 3-D space.
The present manuscript argues that vision and touch cannot be equated because the sensitivity and the processes involved in the attainment of information differ between the modalities. Further, vision is useful for haptics only so long as it provides relevant information. The hand is an important source of information in haptic touch. Evidence shows that though one may have a hand preference, the ability of the non preferred hand cannot be undermined as compared to that of the preferred hand. Research indicates that the hands do not differ in tactile ability, and the seemingly lower performance of the non preferred hand is a consequence of its spatial orientation during performance and not an absence of ability.

Haptic touch and hand ability

Several studies have compared visual perception, tactile (haptic) perception, and visual-haptic perception of stimuli (e.g. Easton, Greene, & Srinivas, 1997; Millar, 1981; Abravanel 1971; Lobb, 1965; Rudel & Teuber, 1964). Often, performance in tasks involving unimodal visual perception exceeds performance in both unimodal haptic and cross-modal tasks. But not always: Norman, Norman, Clayton, Lianekhammy, and Zielke (2004), for example, found that unimodal haptic comparisons of natural three-dimensional shapes could be as good as visual-haptic and haptic-visual comparisons. Norman et al inferred that vision and touch have functionally overlapping, though not equivalent, representations of 3-D space.
Underlying much of the research comparing unimodal visual and tactile perception to cross-modal visual-tactile perception is a long-standing theoretical issue: Do perceivers 'naturally' recognize common features of objects perceived through vision and through touch? Or, alternatively, do accurate cross-modal comparisons develop largely or wholly through experience? Molyneux's famous question about the relation between touch and vision – Can a person born blind distinguish between a cube and a sphere after recovering sight in adulthood? – continues to occupy philosophers (Gallagher, 2004).

In this regard, research has shown that very young infants not only show cross-modal transfer of object properties such as texture and hardness (e.g., Meltzoff & Borton, 1979; Gibson and Walker 1984), but also can recognize by sight objects previously presented to touch (Streri, 1987; Streri & Gentaz 2003). These results challenge the empiricist philosophy and modern connectionist models (McClelland & Rumelhart, 1986; Elman, 1996) that assume independent sensory modalities at birth. Presumably, the capacity found in older children and adults to make cross-modal as well as intramodal comparisons evolve from intrinsic capabilities in infants.

Often, studies of cross-modal perception use a sequential design, which places demands on memory, and demands on memory may matter more to unimodal haptic tasks and cross-modal haptic-visual tasks than to visual tasks (Woods, O'Modhrain, & Newell, 2004). Whether simultaneous presentations of stimuli with lesser demands on memory affect processing differently from sequential presentations was a question of interest. Ittyerah and Marks (2008) therefore compared visual, haptic, and visual-haptic discrimination of curvature stimuli when the two stimuli within each pair were presented simultaneously. Figure 1 depicts each of the six stimuli, which differ only in curvature. Stimulus 1 has a difference of 3.81 mm between its midpoint and its height at the ends. Stimulus 2 has a difference of 5.08 mm between its midpoint and the height at its ends and, therefore, has greater curvature than stimulus 1. The remaining stimuli vary similarly, such that stimulus 6 has the greatest curvature and stimulus 1 the least curvature.

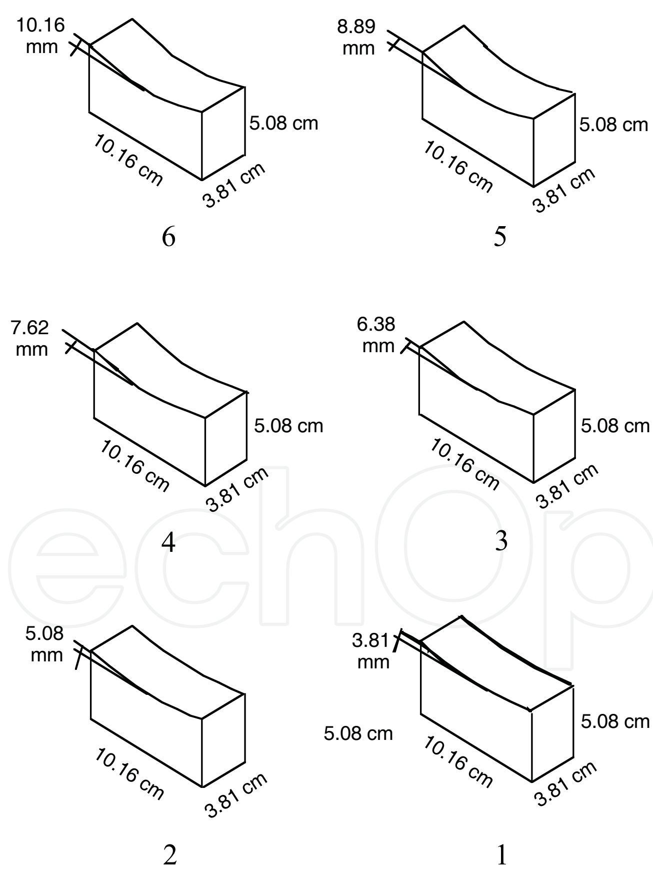

Fig. 1. Dimensions of the six stimuli used in Experiment 1.

With permission from the Editors of Current Psychology Letters. Ittyerah, M. & Marks, L.E. (2008) Intra-modal and cross-modal discrimination of curvature: Haptic touch versus vision. Current Psychology Letters, 24, 1-15.

The findings of Ittyerah and Marks (2008) indicated that when two object surfaces, either the same or different in curvature, were presented simultaneously for comparison, unimodal visual performance exceeded cross-modal performance, which in turn exceeded unimodal haptic performance. Figure 2 shows that the accuracy of responses to same pairs of stimuli is much smaller with haptic comparison than with intramodal visual or with cross-modal comparison. And accuracy of responses to different pairs is also smallest, by and large, with intramodal haptic comparison. As Figure 3 shows, over the three smallest physical differences, where the measures of d′ are most reliable and least susceptible to variability associated with extreme proportions, unimodal visual performance exceeds cross-modal performance by about one d′ unit, essentially, one standard deviation unit, and cross-modal performance similarly exceeds unimodal haptic performance by about one d′ unit.

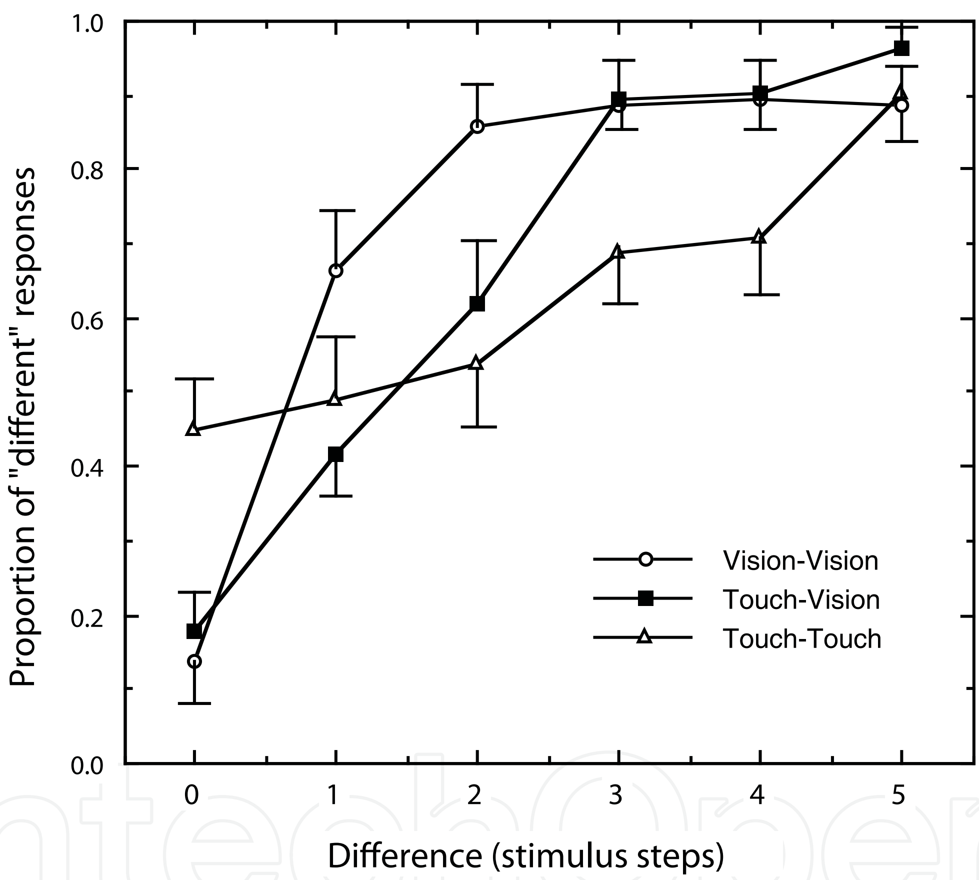

Fig. 2.
With permission from the Editors of Current Psychology Letters. Ittyerah, M. & Marks, L.E. (2008) Intra-modal and cross-modal discrimination of curvature: Haptic touch versus vision. Current Psychology Letters, 24, 1-15.

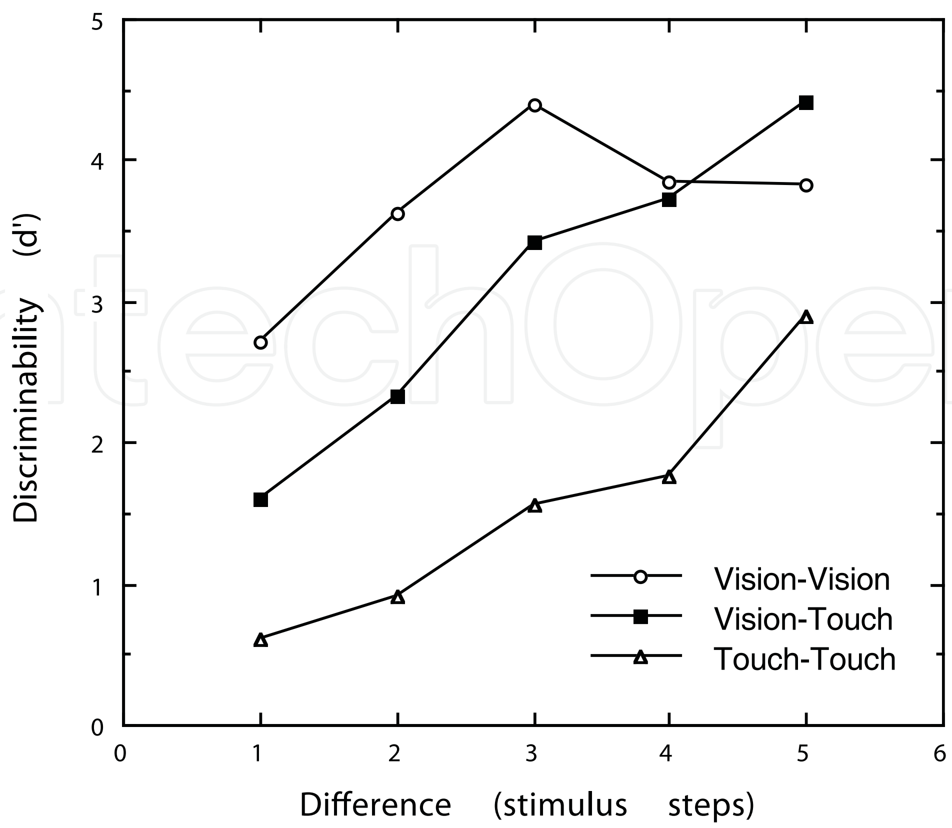

Fig. 3.
With permission from the Editors of Current Psychology Letters. Ittyerah, M. & Marks, L.E. (2008) Intra-modal and cross-modal discrimination of curvature: Haptic touch versus vision. Current Psychology Letters, 24, 1-15.

Haptic perception of form takes place largely by inspection of shapes by the palm and fingers of the hand as they move over the surface of an object. The property of shape or form refers to the spatial layout of the object, which may be specified in terms of contours. An isolated contour may itself be described with respect to its extent and orientation, and interactions among contours, or patterns, may in turn be described in terms of component contours or as combinations of angles, straight or curved surfaces, and other distinctive features. The shapes of many objects may be adequately described in terms of angles and curvatures of various degrees and proportion. In haptic exploration of shapes, the fingers move over the various angles or bend over the curves. The main question of interest is: How do haptic touch and vision compare with regard to people's ability to perceive and remember three-dimensional objects?

A large body of literature concerned with the haptic and visual memory systems has provided two broad accounts. The first is that object memory is multisensory and object representations are shared across modalities if the same object properties are encoded. The second is that objects are stored as modality specific representations that require a recoding from one memory system to another. Such recoding is costly, in time and errors, to cross-modal performance relative to intra-modal performance.

Many recent findings support the idea that visual and haptic memory for objects is shared. For example neuroimaging evidence suggests that the cortical area involved in visual object recognition is also involved in haptic object recognition (Grill-Spector, Kourtzi &

Kanwisheri, 2001). Amedi, Malach, Hendler, Peled and Zohary (2001) reported that activation in the lateral occipital complex (LOC) is not specific to the visual modality. The LOC is also activated during haptic object recognition, though not by auditory information about objects (Amedi, Jacobson, Hendler, Malach & Zohary, 2002). These studies suggest that the LOC is involved in recovering the geometrical shapes of objects (James, Humphery, Gati, Servos, Menon & Goodale, 2002), and behavioural evidence suggests that object representations are shared across modalities (Easton, Greene & Srinivas, 1997; Newell, 2004).

Other studies indicate, however, that tactile memory is not equivalent to visual memory and that information is modality specific. For example, in tests of tactile memory, when a delay intervenes between the presentation of the test stimulus and the test of memory, tactile memory is adversely affected by verbal tasks (counting backwards) interpolated during a 15 sec delay (Gilson & Baddeley, 1969) and by arithmetic tasks after a 5 sec delay (Sullivan & Turvey, 1972). In a study on 3-dimensional object recognition in children, Millar (1974) found that haptic matching performance for nonsense objects was better with an inter stimulus interval (ISI) of 1 sec, than with intervals of 5 and 30 sec, suggesting that haptic memory starts to decay immediately after the exploration of an object.

Other studies report that tactile memory can be sustained for 15 sec (Kiphart, Hughes, Simmons & Cross, 1992) and is vulnerable to articulatory suppression (Mahrer & Miles, 2002). However, performance can also be affected by the task demands or stimulus complexity and the degree of familiarity with the objects being explored (Millar 1981). For example Norman, Norman, Clayton, Lianekhammy and Zielke (2004) observed that accuracy of tactile-visual matching differed across different stimuli, though tactile performance improved with exploration time. Norman et al concluded that observers can match objects known only through touch with other objects known only through vision. Recently, Wood, O'Modhrain and Newell (2004) suggested that tactile-visual object recognition may rely on modality specific representations. Although the effect of delay between cross-modal presentations was the same whether the initial object was coded visually or haptically, recall was better after a 0 sec than a 30 sec delay, indicating delay-induced decay in memory.

In view of the different interpretations, Ittyerah and Marks (2007) tested for inter-modal and intra-modal processes involved in memory for concave curved surfaces that are first presented (perceived) haptically or visually and then later compared to surfaces presented either haptically/visually (unimodal comparison) or visually/haptically (cross-modal comparison). Furthermore, by varying the characteristics of the subjects' activity during a 30-second retention interval (dual task design), we sought to illuminate the underlying mnemonic representation mediating the discrimination.

Dual task paradigms have been used to test for the demands of attention on the primary task (Brown 1958; Peterson & Peterson 1959). The paradigm tests the nature of coding in short term memory by interpolating a secondary task during the delay interval between presentation and recall. Dual task paradigms that test visuo-spatial coding often require movement outputs. For example, tracing, pointing or other gestures are used as secondary tasks. Imagining the task during a delay interval instead of actually performing the task produces similar effects. Millar and Ittyerah (1991) for example, showed modality-specific motor memory in blind conditions not only in actual performance but also in imagined conditions, which excluded any influence of visual knowledge. Thus, it is possible to use movement imagery in the recall of guided movements, as imagined movements biased recall as much as actual movements did. Further, articulatory suppression had no effect on performance, implying little or no role for translation of extent of movement into a verbal format. However, the nature of this modality-specific motor memory is still not well understood. The question arises, for example, whether motor memory is represented spatially in terms of spatial extent or extent of movement. Studies of movement have shown that extent of movement is encoded differently from spatial location in short-term memory (Laabs, 1973; Laabs & Simmons, 1981). Short-term memory could rely, therefore, on kinesthesis even when inputs are not coded spatially, although memory for extent of movement is not very accurate.

Are differences between haptic and visual perception of curvature evident in memory? We (Ittyerah and Marks, 2007) expected that haptic, visual, and cross-modal memory will differ in their sensitivity to the activities in which subjects engage during the interference period. During a delay period of 30 seconds between the presentation of a test stimulus and its recall we introduced any one of the four following activities, such as counting aloud, rehearsing the test stimulus visually or haptically, spacing paper clips in equal distances or moving books from one hand to the other, as well as an unfilled delay that served as a control. We expected that tasks requiring spatial processing may have deleterious effects on performance in both modalities, whereas tasks requiring movement should exert greater effects on haptic memory.

The findings indicated that performance was not only better in haptic than visual conditions, but also that the intervening activities exerted greater effects with haptic than visual presentations. Prior evidence has shown that vision improves shape matching and seems to dominate over touch and haptic inputs that involve touch and movement (Held, 1963, 1965; Rock and Victor 1964). It is also generally agreed that vision is most important in spatial tasks (Sendon 1932, Attneave and Benson 1969). Furthermore, two recent studies suggested that noninformative vision can improve perception by touch (Kennett, Taylor-Clarke and Haggard, 2001; Newport, Rabb and Jackson, 2002). These findings are not consistent, however, with the evidence that people who are totally blind from birth can be equally or more proficient than the sighted on spatial tasks (Hollins 1968; Millar 1994). This evidence implies that proficiency varies with the spatial information that is available from other sources. For example, in a spatial location task of six landmarks, Millar and Al-Attar (2005) found that vision affects haptic processing only if vision adds task relevant information. Touch with diffuse light perception that excluded spatial cues and touch without vision did not differ in accuracy of performance. Millar and Al-Attar concluded that the differences between performance with spatially relevant and spatially irrelevant visual information provide new evidence against the hypothesis that vision affects haptic processing even if it does not add task-relevant information. Therefore, the relatively better performance of tactile compared to visual judgments (Ittyerah and Marks 2007) may reflect differences in the relevance of the delay tasks used to probe the tactile and visual systems.

It is conceivable that the differences in mnemonic representations for haptic and visual curvature are related to differences in haptic and visual perceptual processing. Haptic processing depends on movements of the hand or finger over the stimulus and therefore is subject to spatial constraints on motion, whereas visual processing is often global (Navon, 1977) and the sensory detection and discrimination are limited by the physical properties of the stimuli themselves, such as photon counting at low intensities (De Vries, 1943). In linear movement tasks the demands on memory involve the starting and ending locations of the movement (Laabs & Simmons 1981; Millar 1994). For haptically felt curvature the demands on memory seem to be confined to the slope differences over the far ends of the stimulus (Gordon & Morison 1982; Pont et al, 1998; Pont et al, 1997) for both static and dynamic touch of curved strips (Pont et al 1999). The findings of Ittyerah and Marks (2007) suggest, in turn, that memory for haptic and perhaps for visual representations of curvature, perhaps representations of slope, may be particularly disrupted by tasks that involve spatial processing and movement – as assessed with the dual task paradigm used to test for the demands of attention on the primary task (Brown 1958; Peterson & Peterson 1959). Filling the delay interval with a spatial or a movement task in the haptic and visual modalities produces modality-specific interference (e.g., Logie1986). These results, though specific to the present tasks, may be generalized as being important characteristics in the perception of the curvature of objects. Besides, memory for information from touch and movement has been demonstrated by showing effects of coding texture for unfamiliar shapes and kinesthetic coding for unfamiliar movements (Millar, 1999). This indicates distinct effects for tactile memory. Coding can also involve the mental rehearsal of movements (Millar & Ittyerah, 1991) showing modality specific aspects of the input information. However the informational conditions in which such coding depends differ from those in which visual cues are present. Nevertheless, haptic representations are not recoded into visual coordinates, since impaired memory for recognition in one modality is generally dissociated from performance in the other modality (Farah 1990; Reed, Caselli & Farah, 1996).

Role of vision in tactile tasks

The predominance of studies in reaching and grasping attribute successful performance to the ability of the visual modality for aligning the hand and arm to the size and orientation of the object (Halverson1931, 1932, 1937, Caster 1932, McGraw 1945, Bower 1972, von Hofsten 1982, Jeannerod, 1994; 1997a, b). The role of vision is undoubtedly facilitating, but speculations as to whether it is a necessary modality in the attainment of these specific behaviours can only be examined by comparing congenitally blind children with sighted cohorts. Fraiberg (1968) in extensive work with eight blind infants found that these infants first reached for objects only at the age of ten months, whereas sighted infants on an average reach at the age of five months. Fraiberg (1968) observed that developmental delays in other behaviours of locomotion such as crawling suggested that reaching is the critical skill to locomotion. According to Fraiberg, reaching in blind infants is a two stage process where the initial reaches are to sounding objects pulled from the children's hands and this is followed by reaching to sounding objects held directly before them. Whereas sighted infants spontaneously reach for objects they see, blind infants need to be prompted by sound. If sounding objects are not present, the blind infant may not reach. Therefore reaching is dependent on the awareness of spatial information about the object. Subsequently, Adelson and Fraiberg (1974), Fraiberg (1977) observed that tasks requiring postural control are unaffected, whereas those requiring selfinitiation and mobility are delayed in blind children. Indeed Hatwell (1987) has cogently argued that in instances when blind infants do not use their hands as a perceptual information seeking device (e g. Fraigberg 1977), the reaching behaviour of these infants is mainly a motor executive one where for example the hand is usually used for putting objects in the mouth, and the deficit if any is non-modality specific (e.g. Friedman, 1971). When blind infants reach, this behaviour may be related to their conceptual development (Bigelow 1986). For example, the ear hand coordination for reaching objects in blind children is attained at eight months, whereas eye hand coordination in sighted children is attained by four months. Nevertheless sighted children are not able to reach a hidden object they hear until they are about eight or nine months of age and this is at par with the ages of the attainment of object permanence in blind children. Therefore blind and sighted children do not differ in their understanding of the object concept and vision is neither a necessary modality for the attainment of object permanence and subsequent cognitive development.

Bigelow (1986) found that in instances in which touch and sound are used in analogous tasks, the touch tasks are easier. The infant would rather reach for a toy placed on its chest than for a rattle held before her/him. Children respond to continuous touch before they respond to continuous sound and children reach to cues of previous touch before they reach to cues of previous sound. When touch and sound cues are in conflict, children initially respond to touch cues. Fraiberg (1968; 1977) observed that blind children reached at the body mid-line such as the chest for sounding objects taken from their hands before they reached at mid-line for objects on sound cues alone. Fraiberg concluded that the mid-line is the first space to have subjective reality for blind infants.

There is some evidence that Fraiberg's findings of reaching in blind infants may be operational in sighted infants as well. Wishart, Bower & Dunkheld (1978) studied reaching in sighted infants in dark conditions so that though infants heard the object, they were unable to see the object or know the direction of their reach. Wishart et al (1978) observed that as in the case of blind infants, directional reaches to objects as in off centre positions were more difficult than reaches to objects at the mid-line for sighted infants as well. Therefore there are no fundamental differences in reaching with or without vision. Blind children attain comparable performance with the sighted by relying on self referent cues (Millar, 1981) and self referent cues have been found to be reliable (Stelmach & Larish, 1980). Fraiberg (1968) has shown that this is evident in early infancy when infants reach to their body mid-line for objects they have not seen. Thus the difference between the blind and sighted children may be in the strategies for attaining information and is not a function of visuo-motor control (Jeannrod, 1984, 1994). The fact that blind children between the ages of 6 and 15 years are able to perform acts of reaching, grasping and assessing objects of various sizes using the precision grip (Ittyerah, 1993, 2000, 2009) both with the preferred and nonpreferred hands indicates that though vision may provide complementary information the visual modality is not necessary to perform tactile hand ability tasks because convergent information may be attained from other sources (Millar, 1994). Hatwell (1987) has argued that early in development infants rely on tactile information and perceive objects held in their hands without much assistance from vision. It is only after the age of five or six months that vision dominates and infants become dependent on eye hand coordination. For example when the hands of the infants were occluded by a screen (Streri & Pecheux, 1986 a & b) so that they could not see objects held in their hands, infants displayed a haptic habituation to the familiar stimulus and a novelty response to a new shape as early as four months of age. After five months, there seemed to be an increased synchronization between manual and visual inspection of objects (Rochat 1985). Hatwell (1987) reported that infants aged five to six months displayed suppression in their grasping response when a screen was placed on their shoulders to prevent them from seeing their hands. Although these children did not display any signs of distress nor try to remove the screen, they did not close their hands on the object the experimenter tried to put in it and their hands tended to avoid contact with the object. Over 60% of the infants failed to perform similar unimodal haptic tasks after five months of age or above whereas only 20 % failed to perform unimodal haptic tasks at ages less than four months. Therefore vision clearly dominates at older ages and infant's haptic perceptual abilities begin to be underutilized. Thus early in development, the tactile- haptic system takes precedence over visuo-motor channels for object perception and action.

The relation between hand preference and hand ability

Early reaching behaviours are an indication of hand preference. The difference between handedness and hand ability is that handedness refers to a consistent preference for one hand for executing fairly skilled actions such as writing or sewing. Hand ability refers to the potential capability of each hand in executing the same or different actions and the tacit understanding is that ability for a particular hand action does not differ between the hands. For example, one could write with either hand if encouraged early during development, and differences if any between the hands may be in hand orientation during performance and not in ability (Ittyerah 1996; Ittyerah et al. 2007). The right and left hands of children were able to point at proprioceptive memorized targets, but differed in orientation, in that the right preferred hand was more context oriented and therefore supple, whereas the left nonpreferred hand was more egocentrically oriented and consequently less supple. It may be useful to clarify the notions of hand skill and ability, in order to argue that there is equipotentiality between the hands.

The literature on hand skills may be grouped into three domains of explanation. One view asserts that the preferred hand is the skilled hand (Annett 1972, Annet et al 1979, Honda 1984). Another opinion is that handedness is not a unidimensional variable and hand actions may be grouped according to the muscle groups involved in performing the tasks (Plato et al 1984, Healey et al 1986, Steinhuis and Bryden 1989, 1990). A third opinion holds that the hands may not differ in skill for any action. The performance of both hands may be as good as each other and may depend upon conditions of task demands (Millar 1984, 1987, Ittyerah 1993, 2000, 2009, Millar 2008). It is of interest in this manuscript to examine these differing explanations of hand skill in order to conclude that there is equipotentiality between the hands, although studies of equal ability in the hands may be out numbered by studies that relate hand preference with hand skill.

Is the preferred hand the skilled hand?

Explanations of handedness have indicated a relation between hand preference and hand ability (Annett et. al, 1979, Peters, 1980). They believed that if hand preferences can be coordinated with an independent measure of hand skill, then the understanding of what is handedness can be clarified. Annett (1970b) indicated that the difference between the hands for the peg moving times was highest for the right handers and decreases linearly for the mixed and left handers. Attempts to train the non preferred hand to equal the skill of the preferred hand have not been successful for peg moving (Annett, Hudson & Turner, 1974) nor for finger tapping (Peters, 1976). Annett and Kilshaw (1983) found that degrees of mixed hand preferences between consistent right and consistent left are systematically related to degrees of L-R skill in the peg moving task, and Peters and Durding (1978) found a linear relationship between L-R mean tapping rates and hand preference. These findings led Annett (1985) to conclude that although practice can improve the performance of the non preferred hand, it does not alter the underlying natural asymmetry between the hands. A related notion to the above conclusion is that hand preferences are an out come of eye hand coordination and that eye hand coordination is more efficient on the right than the left side of the body (Woodworth1889, Annett et al, 1979; Peters 1976, 1980; Honda 1984).

Is handedness task specific?

A second group of studies do not consider handedness to be a unidimensional variable, but claim that hand actions may be controlled by groups of muscles that perform various actions and that the more skilled actions such as writing are more lateralized than less skilled actions such as picking up objects(Steinhuis and Bryden 1989, 1990). Reviews of studies on the origin of handedness (Hopkins, 1993) indicate that the earliest signs of hand preference appear to be task specific, in that hand actions are dependent on whether the task involves control of the proximal muscles as for reaching or the control of the distal segments of the hand, as for grasping. Subsequently, Ittyerah (1996) indicated that during development hand preferences may group together into a single category of skill for each hand; the right hand being better at actions of accuracy as in writing or throwing (Healey et al, 1986), and the left hand being more able for acts of strength as in lifting objects (Healey et al, 1986; Peters, 1990).Therefore task demands may dictate hand actions, though the general ability of the hands may not differ.

Do the hands differ in skill?

The question as to whether a particular hand is more skilled than another has not been satisfactorily answered. In nonprehensile tasks such as Braille reading, type writing or piano playing or for prehensile actions of juggling, the hands have a complementary role in task performance. This indicates that the skill is not lateralized, but rather, that task requirements dictate hand actions. For example, there was some initial confusion as to whether Braille is predominantly read by one hand. Superior Braille performance was reported for the left hand (Hermelin & O'Connor, 1971; Rudel, Denckla & Hirsch, 1977), at other times for the right hand (Fertsch, 1947), or for neither hand (Bradshaw, Nettleton & Spehr, 1982; Millar, 1977) and for two handed reading (Foulke, 1982). Millar (1984) has argued that in so far as reading levels are reported, the discrepant findings indicate a pattern that conforms to the notion that highly proficient reading depends mainly on verbal strategies and skill (right hand / left hemisphere advantage); less proficient reading demands attention to spatial coding of the physical characters (left hand / right hemisphere advantage), while early in learning subjects rely on dot density or texture features of Braille characters.

The finding that the general lateralization does not affect ability (Ittyerah 1993, Ittyerah 2000, 2009) indicates, that although one may have a hand preference, there is equipotentiality between the hands. In nonprehensile tasks such as braille reading, Millar (1987) found that fluent braillists use both hands in intermittent alternation for processing text. As to whether this is also true for prehensile actions can be known by testing for hand ability.

Studies in which blind and sighted children were required to match tactile stimuli separately with the left and right hands have indicated that the hands do not differ in tactile ability. Sighted blindfolded and congenitally blind children between the ages of 6 and 15 years were able to match the length, breadth, height and volume of three dimensional bricks of varying sizes with the left and right hands. Results indicated that performance improved with age, though the hands did not differ (Ittyerah, 1993) while performing different manual dexterity tasks such as sorting, finger dexterity and the Minnesota rate of manipulation test. Although there were differences between the groups and ages, the left and right hands of the blind and sighted children did not differ in speed or accuracy (Ittyerah, 2000). However one might argue that the lack of performance differences between the hands for the sighted children may have been a consequence of their temporary blind fold condition that may have interfered with performance, or the lack of differences in the blind children may have been due to a lack of familiarity with the tasks. In a follow up study congenitally blind and sighted blind folded children (Ittyerah 2009) were tested using a sorting task, a stacking task, the finger dexterity test and the Minnesota rate of manipulation test. Performance was assessed for the left and right hands, both before and after a four months practice period. Results indicated an increasing post test gain for all the groups on the tasks with age, though the hands did not differ in performance neither before nor after practice. The consistent results indicate that even if there is a hand preference (Ittyerah, 1993, 1996, 2000, 2009), the general ability of the hands in most tactile tasks does not differ. Thus there is no effect of hand on ability in prehensile tasks as well. The systematic data indicate no significant performance differences between the hands, thus lending support to the present theoretical notion of equipotentiality between the hands. Furthermore, lack of sight does not affect hand ability, just as vision does not determine the direction or the degree of hand preference (Ittyerah, 1993, 2000, 2009).

Visuo-spatial proficiency in the absence of vision

Even if speculations about lack of differences between the hands in the sighted children may be attributed to their temporary blindfold conditions which can be expected to hamper the performance of the preferred hand, there is no reason to expect a similar decline among the blind children who are also mostly right handed. Therefore though vision may provide external references for the sighted, the blind are found to use self reference cues during performance and visuo-spatial proficiency is found to improve under blind conditions as well (Liben, 1988; Millar, 1994). Body centred coding is not confined to the position of the limbs relative to each other or to other body parts. Body centred frames can also be used to code object locations, for example, by coding the hand position which is touching an object by reference to the body midline. When subjects are stationary in blindfold conditions, information is restricted to personal space that is, to spatial locations within the arms reach without moving bodily to another place. Such conditions are of particular interest in studying both short and long term effects of modes of perception on coding.

An absence of differences between the hands both with and without practice, indicates an equally good performance with both hands in the total absence of vision for prehensile movements that involve sorting and stacking of objects, the finer coordination of the thumb and forefinger as in finger dexterity tasks and the general ability of the fingers of both hands in the manipulation tasks. Therefore vision does not affect the general maturation of the child since the blind can gain in proficiency with practice of visuo spatial tasks in the total absence of vision. This proficiency is not only confined to the preferred hand but is also to the same extent in the nonpreferred hand. Findings indicate no effect of hand on ability and suggest equipotentiality between the hands for both prehensile and nonprehensile actions.

The reference hypothesis

The hands are most often used to perceive and discriminate objects by touch. The tactile perception of an object is more accurate with systematic than unsystematic exploration. Accurate haptic coding of information is dependent upon reference frames. The importance of reference frames for accurate coding of movements was emphasized by Jeannerod (1988), Paillard (1991) and Berthoz (1993). Systematic exploration of stimulus characteristics with the hand or fingers requires an anchor or reference point that can be recognized as the end and starting point of the exploratory movement. To know what is to count as spatial processes independent of hand effects, Millar and Al-Attar (2003b) tested two hypotheses. The first hypothesis that the left hand is better for spatial tasks, predicts a left hand advantage for performance in all conditions. The alternate reference hypothesis predicts significantly greater accuracy in haptic recall with explicit additional reference information than in conditions that do not provide additional reference information.

The reference hypothesis assumes that distance and location judgments are spatial tasks. Haptic distance judgments are not solely kinesthetic inputs. Movement distances should be coded spatially if they can be related to reference information (Millar 2008). Millar and Al-Attar (2003a) found that haptic distance judgments do involve spatial coding. Recall of a repeated small distance was disturbed not only by a movement task, but also by a spatial task that required no movements. In a subsequent study (Millar and Al-Attar 2003b) required subjects to recall distance or locations of hapically felt extents. The control condition consisted of scanning the critical distances or locations in presentation and recall without touching any other part of the display or surround. In the experimental or reference conditions, subjects were instructed to use an actual external frame around the stimuli, and also their body midline for reference. The results showed that the added reference information reduced errors very significantly compared to the normal conditions, regardless of whether the left hand scanned the distance in control and frame conditions and right hand was used for the frame, or whether the right hand scanned the distance in control and frame conditions and the left hand was used for the frame. The left and right hands did not differ from each other in accuracy in either control conditions or in reference instruction conditions. The results supported the hypothesis that the use of external frame and body centred reference cues make haptic distance judgments more accurate. The fact that the accuracy of recall with the left hand did not interact differentially with the increase in accuracy with the instructions to use reference cues showed that scanning the distance would involve left hemisphere processing of the movements as well as the spatial aspects of relocating the end position from the new (guided) starting point, and therefore right hemisphere processes also. Cross lateral effects from both right and left hemisphere processes that inhibit or counterbalance each other would explain why the left hand did not perform better than the right and why it did not relate differentially to the advantage in accuracy from instructions to use spatial reference cues. The important finding was that instructions to use body centred and external frame cues for reference improved recall accuracy for both distance and locations, independently of hand performance, task differences and movement effects. Thus reference information can be used as a reliable test of spatial coding.

Millar and Al-Attar (2004) further tested how egocentric and allocentric coding relate to each other. The hypothesis that haptic targets can only be coded spatially in relation to body centred cues would predict that providing haptic cues explicitly from an external surround would not improve recall accuracy beyond the level found with body centred reference cues alone. If on the other hand the difference in spatial coding is due solely to the lack of external reference information that is normally available in haptic task conditions, providing external haptic cues explicitly for reference in a spatial task should improve recall significantly.

Millar and Al-Attar tested subjects with a spatial task that people might actually encounter in daily living. The task was to remember the precise location of five shape symbols as landmarks that had been positioned randomly as raised symbols along an irregular, but easily felt raised line route. This map like layout had an actual tangible rectangular surrounding frame. Each subject was presented with the map like layout placed on the table and aligned to the subject's body midline. The subjects placed the fingertip of their preferred right hand at the start of the route and scanned the route from left to right in all presentation conditions and briefly stopped on each landmark symbol they encountered on the route, in order that they be remembered for the recall tests.

Millar and Al- Attar (2004) found that disrupting body centred cues by rotation increased errors significantly compared to intact body centred coding in the body aligned condition. The critical results were a significant decrease in positioning errors with added external reference information when body centred coding was disrupted by rotation, compared to the rotation condition that lacked external reference information. The condition with intact body centred cues and added external reference information was more accurate in comparison to the body aligned condition without external cues, and more accurate also than the condition with added external information, when body centred coding was disturbed by rotation. Further, accuracy with added external reference information but disrupted body centred coding did not differ from intact body centred coding without external reference information.

The experimental manipulation of separating and combining external and body centred reference showed that external reference cues can also be used with purely haptic information and this seems to be as equally effective for spatial coding as is body centred reference information (Millar and Al-Attar 2004).

In summary haptic touch and hand ability are related. The preferred hand is not necessarily the skilled hand and performance of the left and right hands indicate near equal hand ability. The hands differ in their orientation of performance though haptic perception and identification of objects rely on a frame of reference. Identification of differences in shapes and sizes of objects by touch rely on different reference information. Object identification is possible with either hand early in development in both blind and sighted blindfolded conditions and there is no effect of hand on ability.

References

Abravanel, E. (1971). Active detection of solid-shape information by touch and vision. Perception & Psychophysics, 10, 358-360.

Adelson, E., Fraiberg.S. (1974). Gross motor development in infants blind from birth. Child Development, 45, 114-126.

Amedi, A., Jacobson, B., Malach, R. & Zohary, E. (2002). Convergence of visual and tactile shape processing in the human lateral occipital complex. Cerebral Cortex, 12, 1202-1212.

Amedi, A., Malach, R., Hendler,T., Peled, S. & Zohary, E. (2001). Visuo-haptic object activation in the ventral visual pathway. Nature Neuroscience, 4, 324-330.
Annett, J.; Annett, M.; Hudson, P. T. W.; &Turner, A. (1979) The control of movement in the preferred and non preferred hands. Quarterly Journal of Experimental Psychology, 31, 641-652.
Annett, M. & Kilshaw, D. (1983). Right and left hand skill II: Estimating the parameters of the distribution in L-R differences in males and females. British Journal of psychology, 74,269-283.
Annett, M. (1970b). The growth of manual preference and speed. British Journal of Psychology, 61, 545-558.
Annett, M. (1972). The distribution of manual asymmetry. British Journal of Psychology, 63, 343-358.
Annett, M. (1985). Left, right, hand and brain: The right shift theory. LEA, London. Annett, M. Hudson, P.T.W; &Turner, A. (1974). The reliability of differences between the hands in motor skill. Neuropsychologia, 12,527-531.
Attneave, F. & Benson, B. (1969). Spatial coding of tactual stimulation. Journal of Experimental Psychology, 81, 216-222.
Berthoz, A. (Ed) (1993). Multisensory control of movement. Oxford, UK, Oxford University Press.
Bigelow, A. (1986). The development of reaching in blind children. British Journal of Developmental Psychology, 4, 355-366.
Bower, T.G.R. (1974). Development in infancy. San Francisco: W. H. Freeman.
Bradshaw, J.L., Nettleton, N.C., & Spehr, K.(1982). Braille reading and left and right hemispace. Neuropsychologia, 20: 493-500.
Brown, J.A. (1958). Some tests of the decay theory of immediate memory. Quarterly Journal of Experimental Psychology, 10, 12-21.
Castner, B.M. (1932). The development of fine prehension in infancy. Genetic Psychology Monographs, 12, 105-193.
De Vries, H.L. (1943). The quantum character of light and its bearing upon threshold of vision, the differential sensitivity and visual acuity of the eye. Physica, 10, 553-564.
Easton, R.D., Greene, A.J., & Srinivas, K. (1997). Transfer between vision and haptics. Memory for 2 D patterns and 3 D objects. Psychonomic Bulletin and Review, 4, 403-410.
Elman, J. L. (1996). Rethinking innateness: A connectionist perspective on development. Cambridge, MA: MIT Press.
Farah, M.J. (1990). Visual agnosia: Disoders of object recognition and what they tell us about normal vision. Cambridge, MA: MIT Press.
Fertsch, P. (1947). Hand dominance in reading braille. American Journal of Psychology, 60: 335-349.
Foulke, E. (1982). In W. Schiff & E. Foulke (Eds.) Tactual Perception: A Source Book. Cambridge University Press.
Fraiberg, S(1968) Parallel and divergent patterns in blind and sighted children. Psychoanalytic study of the child, 23, 264-300.
Fraiberg, S. (1977).Insights from the blind. London, UK: Souvenir Press.
Friedman,D.A(1971) Congenital and perinatal sensory deprivation: Some studies in early development. American Journal of Psychology, 127, 1539-1545.

Gallagher, S. (2004). Neurons and neonates: reflections on the Molyneux Problem. In Gallagher, S. (*Ed), How the body shapes the mind.* Oxford: Oxford University Press.
Gibson E.J., & Walker, A. (1984). Development of knowledge of visual- tactual affordances of substance. *Child Development, 55*, 453-460.
Gilson, E.Q., Baddeley, A.D. (1969). Tactile short term memory. Quarterly Journal of Experimental Psychology, 21, 180-184.
Gordon, I.A. & Morrison, V. (1982). The haptic perception of curvature. Perception & Psychophysics, 31, 446-450.
Grill-Spector, K., Kourtzi, Z. & Kanwisher, N. (2001). The lateral occipital complex and its role in object recognition. Vision Research, 41, 1409-1422.
Halverson, H.M. (1937). Studies of grasping responses of early infancy: I, II, III. Journal of Genetic Psychology, 51, 371-449.
Halverson, H.M.(1931). An experimental study of prehension in infants by means of systematic cinema records. Genetic psychology Monographs, 10,107-286.
Halverson, H.M.(1932b). A further study of grasping. Journal of General Psychology, 7, 34-63.
Hatwell, Y. (1987).Motor and cognitive functions of the hand in infancy and childhood. International Journal of Behavioural Development, 20, 509-526.
Healey, J. M., Lederman, J., & Geschwind, N. (1986). Handedness is not an unidimensional trait. *Cortex*, 22, 33-53.
Held, R. (1963). Plasticity in human sensory motor control. Science, 142, 455-462.
Held, R. (1965). Plasticity in sensory motor systems. Scientific American, 213, 84-94.
Hermelin, B., & O'Connor, N. (1971). Functional asymmetry in the reading of Braille, Neuropsychologia, 9, 431-435.
Hofsten, C von. (1982). Eye hand coordination in the newborn. Developmental Psychology, 18, 450-461.
Hollins, M. (1986). Mental haptic rotation: more consistent in blind subjects? Journal of visual impairment and blindness, 80, 950-952.
Honda, H. (1984). Functional between- hand differences and out flow eye position information. Quarterly Journal of Experimental Psychology, 36A , 75-88.
Hopkins, B. (1993). On the developmental origins of handedness. Annual report. Research and clinical centre for child development. Hokkaido University, Sapporo, Japan.
Ittyerah, M & Marks L. E (2008). Intramodal and cross-modal discrimination of curvature: Haptic touch versus vision *Current Psychology Letters*, Vol. 24, Issue 1, 1-15.
Ittyerah, M, Gaunet, F & Rossetti, Y (2007) Pointing with the left and right hands in congenitally blind children. Brain and Cognition, 64 (2) 170-183.
Ittyerah, M. & Marks, L.E. (2007) Perception and Memory in Curvature stimuli. Haptic Touch versus Vision. British Journal of Psychology, 98, 589-610.
Ittyerah, M. (1993). Hand preferences and hand ability in congenitally blind children. *Quarterly Journal of Experimental Psychology*, 46B, 35-50.
Ittyerah, M. (1996). Do the hands differ in skill? *Brain and Cognition*, 32, 2, 291-296.
Ittyerah, M. (2009) Hand ability and practice in congenitally blind children.Journal of Development and Physical Disabilities, 21, 329-344.
James, T.W., Humphery, G.K., Gati, J.S., Savos, P., Menon, R.S. & Goodale, M.A. (2002). Haptic study of three dimensional objects activates extrastriate visual areas. Neuropsychologia, 40, 1706-1714.

Jeanneord, M. (1984). The timing of neural prehension movements. Journal of Motor Behaviour, 16, 235-264.
Jeannerod, M. (1994). The hand and the object: The role of the posterior parietal cortex in forming motor representations. Canadian Journal of Physiology and Pharmacology, 72, 535-541.
Jeannerod, M. (1997a). The cognitive neuroscience of action. Cambridge, Mass: Blackwell Publishers.
Jeannerod, M.(1988). The neural and behavioural organization of goal directed movements. Oxford: Clarendon Press.
Jeannerod, M.(1997b). Grasping Objects: The hand as a pattern recognition device. In Hepp-Reymond, M. C. & Marini, G. (Eds). Perspectives of motor behaviour and its neural basis. Basel, Karger. pp.19-32.
Kennett, S., Taylor, C., & Haggard, P. (2001). Non informative vision improves spatial resolution of touch in humans. Current Biology, 11, 1188-1191.
Kiphart, M.J., Hughes, J.L., Simmons, J.P. & Cross, H.A. (1992). Short term haptic memory for complex objects. Bulletin of the Psychonomic Society, 30, 212-214.
Laabs, G. J. & Simmons, R. W. (1981). Motor memory. In D. Holding (Ed.), Human skills (pp. 119-151). New York: Wiley.
Laabs, G. J. (1973). Retention characteristics of different reproduction cues in motor short-term memory. Journal of Experimental Psychology, 100, 168-177.
Liben, L.S. (1988). Conceptual issues in the development of spatial cognition. In J. Stiles-Davis, M. Kritchevsky, & U. Bellugi (ed.) Spatial Cognition. Hillsdale, New Jersey: LEA.
Lobb, H. (1965). Vision versus touch in form discrimination. Canadian Journal of Psychology, 19, 175-187.
Logie, R.H. (1986). Visuo-spatial processing in working memory. Quarterly Journal of Experimental Psychology, 38A, 229-247.
McClelland, J.M., & Rumelhart, D.E. (1986). Parallel distributed processing: Explanations in the microstructure of cognition. Psychological and biological models, 2. Cambridge, MA: MIT Press.
McGraw, M. B. (1945). The neuromuscular Maturation of the Human Infant. New York: Columbia University Press.
Meltzoff, A.N., & Borton, R. W. (1979). Intermodal matching by human neonates. *Nature, 282*, 403-404.
Millar, S & Al Attar, Z. (2005). What aspects of vision facilitate haptic processing? Brain and Cognition, 59, 258-268.
Millar, S. & Al-Attar (2003a). How do people remember spatial information from Tactile maps? British Journal of Visual Impairment, 21, 64-72.
Millar, S. & Al-Attar (2004). External and body centred frames of reference in spatial memory: Evidence from touch. Perception & Psychophysics, 66, 51-59.
Millar, S. & Al-Attar(2003b). Spatial reference and scanning with the left and right hand. Perception, 32, 1499-1511.
Millar, S. (1974). Tactile short term memory by blind and sighted children. British Journal of Psychology, 65, 253-263.
Millar, S. (1977). Early stages of tactual matching. Perception, 6: 333-343.

Millar, S. (1981). Crossmodal and intersensory perception and the blind. In R.D. Walk & H .C. Pick (Eds.), Intersensory perception and sensory integration (pp. 281- 314). New York: Plenum.
Millar, S. (1987a). The perceptual window in two handed braille. Do the left and right hands process braille simultaneously? Cortex, 23, 111-122.
Millar, S. (1994). Understanding and representing space: Theory and evidence from studies with blind and sighted children. Oxford: Clarendon Press.
Millar, S. (1999). Memory in touch. Psicothema, 11, 747-767.
Millar, S. (2008). Space and Sense. Psychology Press, Hove and New York.
Millar, S., & Ittyerah, M. (1991). Movement imagery in young and congenitally blind children: mental practice without visuo-spatial information. International Journal of Behavioral Development, 15, 125-146.
Navon, D. (1977). Forest before trees. The precedence of global features in visual perception. Cognitive Psychology, 9, 353-383.
Newell, F.N. (2004). Crossmodal object recognition. In C. Spence, G. Calvert & B. Stein (Eds.), Handbook of multisensory integration. Cambridge, MA: MIT Press.
Newport, R., Rabb, B., Jackson, S.R. (2002). Non informative vision improves haptic spatial perception. Current Biology, 12, 1661-1664.
Norman, J.F., Norman, H.F., Clayton, A.M., Lianekhammy, J., & Zielke, G. (2004). The visual and haptic perception of natural object shape. Perception & Psychophysics, 66, 342-357.
Paillard, J. (1991). Motor and representational framing of space. In J. Palliard (ed). Brain and Space. Oxford, Oxford University Press. pp 63–181
Peters, M .& Durding, B.(1978). Handedness measured by finger tapping. A continuous variable. Canadian Journal of Psychology, 32,257-261.
Peters, M. (1980). Why the preferred hand taps more quickly than the non preferred hand. Three experiments on handedness. Canadian Journal Psychology, 34, 62-71.
Peters, M. (1990 c). Phenotype in normal lefthanders. An understanding of phenotype is the basis for understanding mechanism and inheritance of handedness. In Coren (Ed). Left handedness. Behavioural implications and anomalies (pp. 167–192). North Holland: Elsevier Science Publishers.
Peters, M.(1976). Prolonged practice of a simple motor task by preferred and non preferred hands. Perceptual and Motor skills, 43, 447-450.
Peterson, L.R., & Peterson, M.J. (1959). Short-term retention of individual verbal items. Journal of Experimental Psychology, 58, 193-198.
Plato, C. C; Fox, K. M; & Garruto, R.M. (1984). Measures of lateral functional dominance: Hand dominance. Human Biology, 56, 259-276.
Pont, S., Kappers, A.M.L., & Koenderink, J.J. (1997). Haptic curvature discrimination at several regions of the hand. Perception & Psychophysics, 59, 1225-1240.
Pont, S., Kappers, A.M.L., & Koenderink, J.J. (1998). The influence of stimulus tilt on haptic curvature matching and discrimination by dynamic touch. Perception. 27, 869-880.
Pont, S., Kappers, A.M.L., & Koenderink, J.J. (1999). Similar mechanisms underlie curvature comparison by static and dynamic touch. Perception & Psychophysics, 61, 874-894.
Reed, C.L., Caselli, R.J., Farah, M.J. (1996). Tactile agnosia: Underlying impairment and implications for normal tactile object recognition. Brain, 119, 875-888.

Rock, I & Victor, J. (1964). Vision and touch: an experimentally created conflict between two senses. Science, 143, 594-596.

Rudel, R.G., & Teuber, H.L. (1964). Crossmodal transfer of shape information by children. Neuropsychologia, 2, 1-8.

Rudel, R.G., Denckla, M.B.,& Hirsch, S.(1977). The development of left hand superiority for discriminating Braille configurations. Neurology, 27, 160-164.

Sendon. M. Von. (1960). Space and sight: The perception of space and shape in congenitally blind patients before and after operation. London, Methuen.

Steinhuis, R. E. & Bryden, M.P. (1990). Reliability of hand preference items and factors. Journal of Clinical and Experimental Neuropsychology, vol.12. 6, 921-930.

Steinhuis, R.E.& Bryden, M.P.(1989). Different dimensions of hand preference that relate to skill and unskilled activities. Cortex, 25, 289-304.

Stelmach, G, E and Larish, D.D. (1980). Egocentric referents in human limb Orientation. In G.E. Stelmach and J Requin (ed). Tutorials in Motor Behaviour. Amsterdam: North-Holland Publishing Co.

Streri, A. (1987). Tactile discrimination of shape and intermodal transfer in 2- to 3- month old infants. *British Journal of Developmental Psychology, 5,* 213-220.

Streri, A., & Gentaz, E. (2003). Cross-modal recognition of shape from hand to eyes in human newborns. *Somatosensory and Motor Research, 20*, 11-16.

Streri, A., & Pêcheux, M. G. (1986). Tactual habituation and discrimination of form in infancy: A comparison with vision. Child Development, 57, 100-104.

Sullivan, E.V. & Turvey, M.T. (1972). Short term retention of tactile stimulation. Quarterly Journal of Experimental Psychology, 24, 253-261.

Wishart, U.G., Bower, T.G.R. & Dunkeld, J. (1978). Reaching in the dark. Perception, 7, 507-512.

Woods, A.T., O'Modhrain, S., & Newell, F.N. (2004). The effect of temporal delay and spatial differences on cross-modal object recognition. *Cognitive, Affective and Behavioural Neuroscience*, 4, 260-269.

Woodworth, R. S. (1898). The accuracy of voluntary movement. Psychological Review Monograph supplement. No 3.

Advances in Haptics

Edited by Mehrdad Hosseini Zadeh

ISBN 978-953-307-093-3
Hard cover, 722 pages
Publisher InTech
Published online 01, April, 2010
Published in print edition April, 2010

Haptic interfaces are divided into two main categories: force feedback and tactile. Force feedback interfaces are used to explore and modify remote/virtual objects in three physical dimensions in applications including computer-aided design, computer-assisted surgery, and computer-aided assembly. Tactile interfaces deal with surface properties such as roughness, smoothness, and temperature. Haptic research is intrinsically multi-disciplinary, incorporating computer science/engineering, control, robotics, psychophysics, and human motor control. By extending the scope of research in haptics, advances can be achieved in existing applications such as computer-aided design (CAD), tele-surgery, rehabilitation, scientific visualization, robot-assisted surgery, authentication, and graphical user interfaces (GUI), to name a few. Advances in Haptics presents a number of recent contributions to the field of haptics. Authors from around the world present the results of their research on various issues in the field of haptics.

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821