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**Cognitive Novelty and Hemispheric Asymmetry:
Implications for Lateral Transfer of Training
in Normals**

by

Joseph L.B. Dubé

A thesis submitted to the
Department of Psychology
in partial fulfillment of
the requirements for the degree of

Master of Arts

Carleton University

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Research acceptance of the thesis:

**“Cognitive Novelty and Hemispheric Asymmetry:
Implications for Lateral Transfer of Training in Normals”**

Submitted by Joseph L. B. Dubé B.A. Honours

in partial fulfillment of the requirements for

the degree of Master of Arts

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Abstract

The effects of cognitive novelty on interhemispheric communication were investigated using the Lateral Transfer of Training paradigm. Parlow and Kinsbourne (1989) observed that transfer of training for an inverted-reversed printing task was greater from the right to the left hand and proposed a “cross-activation” model to explain their findings. These results could be interpreted as support for the idea that there is greater right to left transfer when the task is a highly practiced one. In Experiment 1, 20 right-handed introductory psychology students performed extended training of an inverted-reversed printing task, with either the right or the left hand. This study was designed to determine the most appropriate training intervals to use in the second study. In Experiment 2, lateral transfer was examined in 64 subjects when the task was still “novel” (i.e., after 8 training trials) or after it had become “familiar” (after 18 training trials). Transfer was assessed after a short unfilled interval. Two test trials were completed, using either the opposite or same hand, and averaged. Transfer favoured the left hand in the novel condition, as reported by Parlow and Kinsbourne. No hand difference was found in the familiar condition. These results do not support the view that cognitive novelty plays a role in directional effects in transfer of training. However, the present findings raise questions about the relationship between engrams and transfer proposed by these authors.

Acknowledgements

I would like to give great thanks to Dr. Shelley Parlow for her time, guidance and sense of humour throughout this project. I would also like to thank my family and close friends - Ben, Lynn and Mike for their support, encouragement and belief in my abilities.

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**Cognitive Novelty and Hemispheric Asymmetry:
Implications for Lateral Transfer of Training in
Normals**

Practicing a new task with one hand typically facilitates performance of the opposite untrained hand. That is, the untrained hand benefits from this practice as well as the trained hand. This phenomenon, known as "cross education" or more recently, "lateral transfer of training", has become the subject of recent interest within neuropsychology (e.g., Parlow & Kinsbourne, 1989, 1990). In this context, transfer can be defined as the facilitation in performance of the untrained hand observed on test trials after a period of training with the opposite hand.

Early researchers (e.g., Hicks, 1974; Meier & French, 1965) found lateral transfer to be asymmetrical for an inverted-reversed printing task in that the right hand benefited more than the left hand from opposite-hand training. This finding is explained by a "callosal access" model of interhemispheric communication (Taylor & Heilman, 1980), whereby the direction of greater transfer of training is linked with the absolute specialization of the left hemisphere for manual skills. According to this model, the right hand has direct access to skills learned by the left hand (and stored in the left hemisphere) whereas the left hand has only indirect access across the corpus callosum to skills learned by the right hand (also stored in the left hemisphere).

More recently, Parlow and Kinsbourne (1989) used a different measure of transfer and argued that transfer of training for the inverted-reversed printing task was greater in the right to left direction. They presented a "proficiency" model to explain their findings. These researchers suggested that the directional effect may be linked to the greater proficiency of the left hemisphere/right hand for a language based task and concluded that there is greater transfer from the dominant (more proficient) to the non-dominant (less proficient) hemisphere than vice versa. However, problems with this "proficiency" model led them to propose a third model, called the "cross-activation" model. According to this model, training of the hand contralateral to the hemisphere which is specialized for a particular skill (the dominant hemisphere) may lead to the formation of dual "engrams" or internal representations by a process they called co-activation. This prepares the non-dominant hemisphere and leaves it in a state of readiness to respond. In contrast, training of the hand contralateral to the non-dominant hemisphere leads to the formation of only a single engram within that hemisphere, and no co-activation occurs. This model implies three things: (1) the processing advantage of one hemisphere over the other is linked to the direction of greater transfer of training, (2) the direction of greater transfer can reverse depending upon the nature of the task (which may employ processes for which either hemisphere is specialized), and (3) transfer is greater when dual (independent) engrams are formed in parallel

during training than when a single engram is formed and subsequently “transformed” to the other hemisphere at a later time (see Parlow and Dewey, 1991; for more information).

A fourth model, the “familiarity model”, could also account for Parlow and Kinsbourne's (1989) findings. This assumes that the subject's familiarity with the task is a critical factor in determining directional effects. This model is based on Goldberg and Costa's (1981) theory that the right hemisphere is specialized for processing newly acquired “novel” tasks and the left hemisphere for processing “well learned” tasks. The idea that the amount of practice may be an influential factor in asymmetrical transfer is a provocative one. In Parlow and Kinsbourne's experimental procedure, the amount of practice provided prior to opposite hand performance was held constant for all subjects. However, it is possible that the amount of practice may be an important factor in determining which hemisphere is dominant for a particular task. Parlow and Kinsbourne's results could be interpreted as support for the idea that there is a greater transfer from right to left hand when the task is a highly practiced one.

In order to test the “familiarity” model, Semeniuk (1992) varied the number of practice trials. She found that the direction of greater transfer reversed at low (12 practice trials) and high levels (22 trials) of training. Semeniuk argued that this reflects a shift in relative specialization from right to left hemisphere as the printing

skill became well learned. More specifically, Semeniuk suggested that the "familiarity model" may be viewed as an extension of the cross-activation model by specifically addressing the issue of task novelty as an important factor underlying hemispheric reversal.

The present thesis represents an attempt to replicate the key reversal in the direction of transfer of training for inverted-reversed printing observed in Semeniuk's study. I will be examining the effects of varying the number of practice trials on the direction of lateral transfer for the inverted-reversed printing task. If the direction of greater transfer is found to reverse at low and high levels of training, this may be interpreted to reflect a shift in relative specialization from right to left hemisphere as the printing skill became well learned. This finding would be compatible with both Goldberg and Costa's (1981) model of hemispheric specialization and with the cross-activation model of interhemispheric communication proposed by Parlow and Kinsbourne (1989).

Behavioural evidence for Goldberg and Costa's (1981) theory linking task novelty with hemispheric specialization of function has been provided recently for such tasks as learning Hebrew words (Yoshizaki & Hatta, 1987), face recognition (Ross-Kossak & Turkewitz, 1984), and identifying Japanese ideograms (Kittler, Turkewitz & Goldberg, 1989). For example, Kittler et al. documented a shift in visual field advantage (from left to right) with extensive practice of complex,

initially unfamiliar stimuli (Japanese ideograms). They argued that the right hemisphere is more important for processing these unfamiliar stimuli in the inexperienced subject, but that the left hemisphere is more important later, as competence increases for this task. Similarly, Ross-Kossak and Turkewitz (1987) observed a left visual field (right hemisphere) advantage during early test trials in a face recognition task. A left hemispheric (right visual field) advantage has also been found for non-natives receiving extensive practice with Hebrew words (Yoshizaki & Hatta, 1987), suggesting a greater role played by this hemisphere as the task became well-learned.

Recent work on asymmetrical transfer of braille acquisition in sighted subjects (Parlow & Kinsbourne, 1990) also supports Goldberg and Costa's (1981) theory. Parlow and Kinsbourne found a left hand advantage for this task in their sample and observed greater transfer of training from the left hand to the right hand, reversing their previous findings for the inverted-reversed printing task. They suggested for these inexperienced subjects, the right hemisphere played the dominant role in learning, despite the linguistic nature of the task, and that this affected lateral transfer of training.

The present investigation was conducted to assess the benefit of opposite-hand training after different amounts of training. In Experiment 1, the most appropriate intervals to use (i.e., the number of practice trials) was established. This provided

an objective answer to the question, when is the inverted-reversed task "novel" and when is it "familiar"? In Experiment 2, lateral transfer was assessed after subjects received one of two levels of training. A shift in the direction of transfer after many practice trials would support both the model proposed by Goldberg and Costa (1981) and the cross-activation theory of Parlow and Kinsbourne (1989). Such a result would suggest that perhaps an integrative theory of interhemispheric communication is necessary that takes into consideration both task familiarity and hemispheric specialization.

In the present thesis, I begin by reviewing literature on lateralization of function in the human cerebral cortex. This concept is central to the theories mentioned above (e.g, Parlow & Kinsbourne, 1989; Goldberg & Costa, 1981). Then, each model will be presented in some detail, for comparison purposes. Following this review, I will then discuss individual differences in brain organization, focusing on handedness and gender issues as they are pertinent to the present discussion. This will be followed by a discussion of issues related specifically to the lateral transfer of training paradigm and its use as an index of interhemispheric communication. A discussion of this inverted-reversed printing task used in this thesis will complete this review.

Hemispheric Asymmetries in the Human Brain

A great deal of evidence has accumulated in recent years showing that the left and right cerebral hemispheres are not identical in their abilities or organization. "Cerebral lateralization of function" then, was coined to reflect a hypothetical model of brain organization, according to which the two hemispheres of the brain are specialized for different functions. This model of the brain is widely accepted.

The earliest and most dramatic evidence of functional asymmetry in the human brain has come from clinical observations of the behaviour of individuals with brain damage. For example, early clinical reports by Dax, Broca and Wernicke (cited in Corballis, 1983) documented language problems following left hemisphere damage. In contrast, right hemisphere lesions have typically been shown to disturb visuospatial processes, such as mental rotation (Ratcliff, 1979).

Another source of data is from so-called "split-brain" patients, patients that have undergone commissurotomies (a surgical procedure to cut the corpus callosum; this structure connects the two hemispheres and thus the operation can be said to "split" the cerebral hemispheres) for relief of intractable epilepsy. These patients provide an unparalleled opportunity to study the abilities of each hemisphere separately within the same head (Springer & Deutsch, 1993). Split-brain studies have shown that, although each half of the brain is capable of perceiving, learning, remembering and feeling independently of the other,

differences exist in the way in which each hemisphere deals with incoming information. For example, studies with split-brain patients have shown that the right hemisphere is markedly superior to the left in matching common geometric figures (Ledoux, Wilson and Gazzaniga, 1977).

The investigation of cerebral asymmetries in normal subjects has been carried out in several ways. Studies of lateralization of cerebral function in normals typically involve making inferences based on measures of perceptual laterality (i.e., observable asymmetries of perceptual and motor functioning). By examining various perceptual laterality measures, one can make inferences regarding cerebral laterality for certain tasks.

Visual asymmetries can be studied using the visual half-field technique. Using a tachistoscope (t-scope), stimuli are briefly presented in one or both visual fields as a subject is told to fixate on a point straight ahead. The assumption underlying this method is a simple one and one which has been supported by the brain lesion literature. Simply stated, perceptual speed and accuracy differences favouring one visual field over the other indicates the greater participation of the contralateral hemisphere in the processing of the material (Kimura & Durnford, 1974). Thus, the paradigm allows a researcher to provide input to each hemisphere in isolation. For example, researchers typically observe a right visual field advantage (RVF) for verbal stimuli, including words. This supports the widely held belief that the left

hemisphere is specialized for processing language. In contrast, a left visual field (LVF) superiority is often observed for visuospatial stimuli, believed to be processed by the right hemisphere. Using the t-scope method, Kimura and her colleagues (Kimura, 1966; Kimura & Durnford, 1974) demonstrated a right hemisphere (left visual field) advantage for a variety of visual processes including point location, stereoscopic depth perception, perception of line orientation and dot enumeration. A corresponding left hemisphere advantage was demonstrated for verbal stimuli (spoken nonsense sounds, letters and words).

Techniques to study lateralization of auditory information have also been developed. Kimura (1961a,b, 1967) was an early pioneer of the dichotic listening procedure. This method involves the presentation of auditory stimuli to both ears at the same time. The subject is then tested on their recall of the stimuli presented to each ear. Kimura proposed that normally each ear sends information from all its receptors to both hemispheres. Thus, for example, complete information about a stimulus presented to one ear is normally represented initially in both hemispheres. However, when information is presented simultaneously to both ears, the ipsilateral pathway is suppressed and the contralateral pathway assumes priority. Using the dichotic listening procedures, an advantage will be observed for the ear contralateral to the hemisphere assumed to be dominant for processing that stimulus. In studies using the dichotic listening technique in normal subjects,

Kimura and her colleagues, (Kimura, 1964; King and Kimura, 1972) found a left ear (right hemisphere) advantage (LEA) for vocal non-verbal sounds (i.e., emotional sounds and hummed melodies), and a right ear advantage (REA) when the stimuli presented were words, digits, and nonsense syllables (Kimura, 1967). In subsequent studies on normals using this technique, a right ear/left hemisphere processing advantage in the perception of rhythm and speech sounds and a left ear/right hemisphere advantage in the perception of environmental sounds, melodies, musical pitch, timbre and harmony have also been demonstrated (Corballis, 1983; Bradshaw & Nettleson, 1983).

In the next section, I have chosen to concentrate on reviewing those behavioural asymmetries that are used most often to support claims about the functions for which each hemisphere is dominant.

Quest for "The Fundamental Dichotomy"

One primary theoretical goal of research on hemispheric asymmetries has been to discover a fundamental information-processing dimension along which the hemispheres differ and from which all of the observed behavioural asymmetries could be derived (Hellige, 1993). In fact, according to Hellige, the most parsimonious set would be a "single fundamental dichotomy" that would "underlie all the rest" (1993, p. 54). A great deal has been written about the nature of such a distinction. However, to date, no single distinction has been able to account for all

features of hemispheric function and thus adequately characterize the difference between the hemispheres (Hellige, 1983). Some of the most relevant dichotomies that relate to the present study will be discussed below.

Verbal/Nonverbal Dichotomy

Language is a complex multifaceted skill that encompasses the formation of sounds, the development of sophisticated rule systems, and the existence of vast quantities of meaning and significance information (Springer & Deutsch, 1993). Early clinical reports by Dax, Broca and Wernicke (cited in Corballis, 1983) documented language problems following left hemisphere damage. For a long time after this, all language functions were ascribed to the left hemisphere, and all non-language functions were (by process of elimination) ascribed to the right hemisphere. The verbal/nonverbal dichotomy is still very popular.

A second, related dichotomy that evolved out of this original distinction may be termed linguistic/visuospatial. According to this view, there are two basic and complementary processes, each represented in a different cerebral hemisphere. While the left hemisphere has been associated with many linguistic functions the right is viewed as being specialized for visuospatial processes such as spatial analysis and construction (Benton, 1967), mental rotation (Ratcliff, 1979), "manipulospaciality" (Gazzaniga & Ledoux, 1978), and learning spatial mazes (Milner, 1965).

The verbal/nonverbal dichotomy or some variation of it has been widely employed as a heuristic for characterizing hemispheric differences. However, this distinction has been rejected by Corballis (1983) as it fails to account for some important findings in laterality research. For example, there is good evidence that the right hemisphere contributes to many factors of human behaviour that play a role in communication. For example, right hemisphere lesions have been shown to disturb certain aspects of language production as well as its oral and written comprehension. According to Ardilla (1984), right hemisphere damage can result in alexia (inability to read), agraphia (decline or loss of the ability to write), and in the loss of "graphic automatisms" (e.g., the subject may lose their ability to write their signature). The right hemisphere has also been shown to play important roles in the prosodic and emotional aspects of speech, in the appreciation of humour, and in the processing of extra- or paralinguistic features of language (Wapner, Hamby, & Gardner, 1981). In addition, this hemisphere appears to have a role in the use of imagery-based language and semantic processing (Millar & Whitaker, 1983). Furthermore, the specialization of the left hemisphere is not restricted to language but also extends to motor skills and to nonverbal tasks involving sequential processing (Corballis, 1983).

Given such findings, the adequacy of the verbal/nonverbal dichotomy is in doubt. A description of other popular dichotomies follows.

The Left Hemisphere and Motor Skills

In 1907, Leipmann and Maas (cited in Heilman, 1979) proposed that the left hemisphere is dominant for motor functions as well as language. They speculated that in addition to language functions, the left hemisphere may contain certain types of motor engrams or "movement formulas" that controlled movement for each side of the body. In modern times, Heilman (1979) has proposed that the term "visuokinesthetic motor engrams" be used instead to reflect the fact that control of movement also involved the positioning of body parts in external space over time.

Clinicians have described patients with damage to the left hemisphere but without paralysis of the right side who have difficulty copying a sequence of hand and finger movements with either the left or right hand (Springer & Deutsch, 1993). Findings such as these suggest that the left hemisphere may be dominant for bilateral motor control. In fact, some authors have extended this role to include the temporal control of fine manipulative movements and handedness (Wolff, Hurwitz & Moss, 1977; Bradshaw & Nettleson, 1983). Evidence suggesting right hand superiority in the serial organization of movements (e.g., Wolff, Hurwitz, & Moss, 1977) supports the notion of left hemisphere specialization for fine motor control. This had led some authors (e.g., Corballis, 1983), to argue that the superiority in motor skills demonstrated by the left

hemisphere may actually reflect a more basic superiority in the production and perception of sequences, and in making fine temporal judgements. For example, Carmon (1978) has concluded that left hemisphere lesions lead to an increase in the time required to perceive order and sequencing, irrespective of spatial complexity. In contrast, right hemisphere damage may result in impaired perception in relation to spatial complexity rather than to the perception of sequences. The superiority for temporal sequencing is also reflected in a left hemisphere advantage for rhythmic perception and production (Corballis, 1983). Taking the above observations into account, the left hemisphere can be seen as assuming a dominant role in sequential motor processing.

Focal/Diffuse Brain Organization

Although the two preceding dichotomies are based on functional (t-scope and dichotic) asymmetries and observed hand differences, they do not assume a neuroanatomical basis for hemispheric specialization between the two hemispheres.

Semmes and her colleagues (Semmes, Weinstein, Ghent, & Teuber, 1960) speculated that there may be neuroanatomical differences in neural organization and that this may lead to different functional roles. They observed an apparent asymmetry in the somatosensory system: missile wounds in many different locations in the right hemisphere produced a similar sensory deficit (i.e., lower scores on cutaneous tests, including touch-pressure thresholds and two-point

discrimination) indicating that somatosensory function was diffusely represented throughout the right hemisphere. In the left hemisphere, by contrast, only lesions that invaded the region of the postcentral gyrus produced similar deficits. Similarly, Semmes (1968) found that in patients with unilateral brain damage, sensorimotor impairment was associated with focal lesions in the left hemisphere (usually in the sensorimotor areas). In the right hemisphere, similar impairment was associated with lesions both within and beyond the sensorimotor area, again implying diffuse right hemisphere organization of functions. Based on her previous studies (Semmes et al., 1960; Semmes, 1968), Semmes proposed that the processing of discrete, unimodal stimuli favours the left hemisphere, whereas the diffusely organized right hemisphere can be viewed as specialized for integrating dissimilar elements resulting in multi-modal integration. Semmes concluded that it is important to consider how intrahemispheric organization might bring about "...greater dependence of a given behaviour on one hemisphere than on the other" (1968, p. 21). The fact that the left hemisphere is made up of more grey matter (cell bodies) than the right hemisphere and that there is a greater proportion of white matter (axons) in the right hemisphere than the left hemisphere (Gur et al., 1980) also lends support to this focal/diffuse characterization.

According to Hellige (1993), the idea that the two hemispheres are organized differently is intriguing and it is for this reason that Semmes' argument continues to

be invoked.

Theory of Goldberg and Costa

An important dichotomy for the present investigation was proposed by Goldberg and Costa (1981). Their proposal developed from the work of Semmes and her colleagues (Semmes et al., 1960; Semmes, 1968) and assumes that there are basic neuroanatomical differences in the organization of the left and right hemispheres. Their model also assumes that hemispheric specialization is relative rather than absolute (see the following section). They argued that cerebral lateralization for a particular task may vary depending on its level of familiarity for the subject the level of acquisition. These researchers discuss evidence for differences in neuroanatomical organization of the two hemispheres that may account for two fundamental distinctions in processing. Their model assumes that the right hemisphere is best suited for the integration of novel, multimodal information and the left hemisphere for processing well-learned, unimodal stimuli. This view is supported by many neuroanatomical studies. For example, as mentioned earlier, neuroanatomical evidence from Gur et al., (1980) has shown that there is more white matter (large myelinated fibers) than grey matter (neuronal mass and nonmyelinated fibers) in the right hemisphere. In addition, there is data suggesting that areas devoted to sensory and motor-specific functions are larger in the left hemisphere (LeMay & Culebras, 1972; Galaburda, LeMay, Kemper &

Geschwin, 1978), whereas the right hemisphere is characterized by greater areas of "associative" higher level integrative cortex (Wada, Clarke, & Hamm, 1975).

These findings support Semmes' (1968) proposition that the right hemisphere, because it contains more myelinated white fibers, is structurally more suited for interregional integration while the left hemisphere (by virtue of its greater proportion of grey matter) is more suited for processing modality-specific stimuli and providing intraregional integration of similar elements.

In Goldberg and Costa's (1981) model, effective cognitive strategies are remembered and become incorporated into a "descriptive system". These researchers argue that the right hemisphere is better suited for the assembling of a new descriptive system through the application of multiple encoding strategies. In contrast, the left hemisphere contributes more to processing the task in the later stages once the skills have been routinized through extensive practice, and stored as part of a new descriptive system. Therefore, this model predicts a right to left shift of relative hemispheric specialization for a task once it has become well-learned. Furthermore, Goldberg and Costa emphasized individual differences and argued against assigning fixed hemispheric specialization for particular materials or tasks. They emphasized that "[there is] a gradient of relative hemispheric involvement in a wide range of cognitive processes, reflecting the degree of their routinization" (1981, p. 165).

In addition to the neuroanatomical studies, behavioural evidence of a right hemisphere to left hemisphere shift with practice has recently been documented provided using such tasks as learning Hebrew words (Yoshizaki & Hatta, 1987), face recognition for unfamiliar faces (Ross-Kossak & Turkewitz, 1984), and in identifying Japanese ideograms (Kittler, Turkewitz, & Goldberg, 1989). For example, Kittler, Turkewitz and Goldberg (1989) examined shifts in visual field advantage for the recognition of complex, initially unfamiliar stimuli (Japanese ideograms) in non-natives. Their results demonstrated a shift in hemispheric advantage from right to left with increased competence as revealed by tachistoscopic presentation. Similarly, Ross-Kossak and Turkewitz (1987) found a right hemisphere advantage during the early test trials in a face recognition task. A left hemispheric advantage has also been found for non-natives receiving extensive practice with Hebrew words (Yoshizaki & Hatta, 1987).

Recent work on asymmetrical transfer of braille acquisition (Parlow & Kinsbourne, 1990) also lends support to this theory. Braille is a complex task involving tactually-based language. Parlow and Kinsbourne (1990) have shown greater transfer of training from left hand to right hand for a novel task, such as learning braille, suggesting that the right hemisphere is more important at this stage of processing.

Subsequent studies using regional cerebral blood flow (rCBF) or positron emission tomography (PET) neuroimaging techniques confirm and expand on Goldberg and Costa's (1981) "novel-routinization" hypothesis (Roland, 1982; Nishizawa, Olsen, & Larsen, 1982; Pardo, Fox, & Raichle, 1991). Specifically, there is evidence that the right frontal systems are crucial for cognitive selection driven by the external environment and for context-independent behaviour, the left frontal systems for cognitive selection driven by the content of working memory and for context-dependent behaviour (Goldberg, Podell, & Lovell, 1994). Their work on the lateralization of frontal lobe control over these functions is based on the functional neuroimaging of activation patterns in healthy volunteers and in patients as well as from the observations of frontal lesion effects on behaviour (see review by Goldberg et al., 1994).

Taken together, the evidence supporting the novel-routinization approach is particularly interesting in that it argues against the fixed assignment of materials and tasks to one or the other hemisphere.

Relative/Absolute Specialization of Function

An issue that can be applied to any of the preceding dichotomies is the issue concerning relative versus absolute hemispheric processing superiority. For example, the differences between the hemispheres may be relative, quantitative, and a matter of degree rather than absolute, qualitative, and a matter of kind.

Traditionally, lateralization of function has been considered for the most part to be absolute, in that one or the other hemisphere has a monopoly over a certain function that cannot be shared. The view that left hemisphere is "verbal", the right hemisphere is "not verbal" does not allow, for example, the right hemisphere to play a role in processing some aspects of speech. Today, researchers in this area generally view lateralization of cerebral function as reflecting the greater relative contribution by one hemisphere for different tasks (Joynt & Goldstein, 1975; Bradshaw, 1989). That is to say, one hemisphere may simply be more important in mediating a function as opposed to solely responsible for its mediation. According to this view, both hemispheres share most cortical functions. However, each hemisphere is more or less equipped to handle particular ones (for example, the left might be more specialized for linguistic and verbal elements of a given task and the right for the more spatial and nonverbal elements). As well, lateralization of different subprocesses required in the performance of a complex task may give the impression that a given hemisphere has a processing advantage over the other (Bradshaw, 1989).

Asymmetric Hemispheric Arousal and Individual Differences in Attention Bias

It has also been suggested that the two cerebral hemispheres can differ in terms of level of activation or arousal, and recent studies suggest that individuals can differ with respect to their habitual or characteristic patterns of arousal asymmetry

(e.g., Levy, Heller, Banich & Burton, 1983). These individual differences in arousal-asymmetry may influence (independently of hemispheric specialization) the extent to which stimuli are processed by one hemisphere or the other and subsequently, the performance on a variety of perceptual laterality tasks. For example, although the left hemisphere is considered the dominant one for processing visually presented words, a specific individual may habitually experience increased left hemisphere arousal. This would result in a habitual bias of attention toward the right side of space (Levy et al., 1983), therefore exaggerating the expected right visual field advantage for this material. Conversely, an individual with habitually increased right hemisphere activation would experience an attentional bias toward the left visual field, thereby reducing the expected right visual field advantage for linguistic material. Thus, differences in hemispheric arousal and attention may influence the extent to which stimuli are processed by one hemisphere or the other, and may explain some observed behavioural asymmetries.

Biological Sex and Cerebral Asymmetry

In humans, gender differences have been documented for several cognitive abilities. For example, females tend to score higher than males on tests of verbal fluency and manual skill, whereas males tend to score higher than females on tests of visual perception and spatial ability (Bradshaw, 1989). However, there is

substantial overlap in performance between the two sexes (Hellige, 1983) and the difference in group means and effect sizes are typically small in magnitude (Bradshaw, 1989). The origin of these gender differences in cognitive ability probably lies in a complex interplay between biological and environmental factors (e.g., hormones, social pressures, strategies). At present, we are unable to separate these two factors.

Some have suggested that gender differences in cognitive ability may reflect aspects of hemispheric organization that tend to be different for males and females. For example, Lansdell (1962) speculated that physiological mechanisms underlying visuospatial and verbal abilities overlap in the female but are located in opposite hemispheres in males. Since then, there has been an accumulation of behavioural evidence suggesting that in the male brain, the cerebral hemispheres may be more asymmetrically organized than in the female brain, both for verbal and nonverbal (spatial) functions (see Springer & Deutsch, 1993).

One way to examine sex differences in hemispheric organization is to examine the incidence of certain disorders after unilateral brain injury and determine whether different distributions are obtained for males and females. McGlone (1980) reported that the incidence of aphasia (i.e., impairment of language ability) after damage to the left hemisphere occurred in males three times as frequently than females, which led her to argue that males are more likely to have left hemisphere

representation of language, while females have bilaterally represented language.

It should be noted, however, that alternative explanations exist for this finding.

For example, a major factor that may contribute to the findings with aphasia is that fewer females are left hemisphere dominant for speech (Hellige, 1993). As well, according to Kimura (cited in Hellige, 1993), speech may be represented more focally in the left hemisphere of males and more diffusely in the left hemisphere for females (i.e., organization within the left hemisphere differs).

Several researchers have observed gender differences in the size of the corpus callosum, the major nerve-fiber tract that connects the two cerebral hemispheres (de Lacoste-Utamsung & Holloway, 1982; Bell & Variend, 1985). Most recently, using magnetic resonance imagery (MRI), Allen, Richey, Chai and Gorski (1991) found a dramatic sexual dimorphism in the shape of the posterior corpus callosum.

Although they observed no significant differences in overall size as a function of sex, the splenium (the posterior region of the corpus callosum) was more bulbous shaped in females and more tubular in males. Since this commissure is considered to be of major importance with respect to interhemispheric communication, this may explain the variability in lateralization for females. According to Allen and his colleagues, conflicting reports with respect to the sexual dimorphism of the corpus callosum in the previous literature reflect the fact that measurements have been performed in different ways in different studies and the methodology used has not

always described in detail. Thus, it has been difficult to compare data from different studies. As well, since the size and shape of corpora callosa vary considerably among individuals, larger sample sizes are required than have been presented to date in order to convincingly demonstrate significant sex differences.

Still, it remains to be determined how the size of different regions of the corpus callosum relates to functional hemispheric asymmetry, and whether in fact structural differences within the brains of males and females are linked to differences in their cognitive abilities.

In order to examine the link between sex and lateral transfer of training, both males and females will be studied in the present project.

Cognitive Strategies and Behavioural Asymmetries in Performance

There is evidence that the cognitive strategy chosen in approaching a task may determine the observed cerebral functional lateralization for that task. That is, the direction of laterality may not depend as much on the nature of the task itself but rather how the task is processed or encoded by the subject. Thus, there may be an interaction between task and subject. Different problem-solving strategies used by the two sexes may also affect the apparent lateralization on cognitive tasks.

It has been hypothesized that verbal and imagery strategies (e.g., subvocal rehearsal, forming images) may differentially involve the two cerebral hemispheres independently of the nature of the task. For example, solving a spatial task may be

mediated to some extent by the left hemisphere depending on the degree of "verbal mediation" used by a subject. In addition, Kolb and Whishaw (1990) stress that we must be aware that apparent differences between the two sexes, especially left-right ones, may reflect different strategies of problem-solving which are culturally prescribed for the two sexes rather than real neurological differences. For example, if females tend to solve relatively nonverbal problems using verbal strategies, unilateral brain damage to the right hemisphere might appear to have little effect on this type of task (Kolb & Whishaw, 1990). Thus, the wording of instructions may affect the outcome in psychological investigations of cognitive performance.

Handedness and Functional Asymmetry

As with gender differences, there seems to be a consensus that genetic and environmental factors both play roles in determining handedness, but the mechanisms involved are not yet well understood (Hellige, 1993). While cross-cultural studies put the incidence of right-handedness at about 90 percent (Springer & Deutsch, 1993), the actual incidence is difficult to obtain because the criteria and measurement are so varied in this literature.

The most widely used method to assess handedness is to ask subjects to complete an inventory which asks them to indicate their preferred hand, as well as the strength of their hand preference for a variety of common activities. The most

popular inventory is the Edinburgh Handedness Inventory, developed by Oldfield (1971). This questionnaire yields a laterality quotient that ranges from -100 for extreme left handedness, through 0 for complete ambidexterity, to +100 for extreme right handedness. This assumes that handedness is a continuum, with all degrees of lateralization being represented in the population (Bryden, 1982). However, problems have arisen with preference measures when determining the placement of those weaker preference subjects. One solution is to select only those with the strongest right or left preference. The disadvantage to this selection process is that strongly dominant left-handed subjects are much harder to find in the general population than are strongly right-handed subjects, making this research difficult to conduct (Iaccino, 1993).

Sodium amobarbital testing is a technique used to localize functions across the hemispheres. Here a barbiturate is injected into the left or right carotid artery to temporarily anesthetize that side of the brain. This procedure has shown that over 95 percent of right-handers have speech localized to the left hemisphere, with 70 percent of left-handers showing the same pattern (Rasmussen & Milner, 1977). Of the remaining 30 percent of left-handers, most show evidence of bilateral speech (Loring et al., 1990), while up to 5 percent of right-handers have been shown to have their speech lateralized to the right hemisphere (Rasmussen & Milner, 1977).

The prognosis for recovery from aphasia following stroke has been reported to be much better in left-handers than in right-handers (Luria, 1970). In fact, dichotic-listening and lateralized tachistoscopic studies that compare the performance of left- and right-handers show less evidence of asymmetry in left-handers (Bryden, 1965, Satz, Achenbach, Patteshall, & Fennell, 1965). These findings mesh well with the clinical evidence pointing to a greater bilaterality in left-handers (Springer & Deutsch, 1993).

In the present investigation, only strongly right-handed subjects will be used in order to eliminate possible handedness effects.

General Summary

Early characterizations of functional specialization in the two cerebral hemispheres have focused on absolute dichotomies to account for hemispheric differences. More recently, researchers have proposed that many factors may play a role in laterality effects, including familiarity, hemispheric activation, gender, strategy-use and handedness. In the present investigation, I will be focusing on Goldberg and Costa's (1981) hypothesis that familiarity plays a major role in hemispheric involvement during skill acquisition. Their novel-routinization hypothesis is particularly attractive because it offers a dynamic rather than a static view of hemispheric specialization. That is, it implies that the pattern of hemispheric specialization is different in a given individual at different stages of

processing. Specifically, it implies that the locus of cortical control shifts from the right to the left hemisphere in the course of cognitive skill development. The implications of these concepts of hemispheric specialization for interhemispheric communication will be considered in a later section.

Before describing the present investigation in some detail, I will first discuss some important issues for lateral transfer studies.

Lateral Transfer as a Measure of Interhemispheric Communication

"Interhemispheric communication" can be defined as the way in which the two hemispheres communicate or interact to share control of behaviour. While there are several theories of interhemispheric communication in the literature (to be discussed below), there are relatively few good measures of interhemispheric transfer of information. The most frequently used tools for investigating interhemispheric communication in normal subjects include: (1) electrophysiological methods (e.g., EEG, Evoked Potential), (2) glucose metabolism scanning and blood flow (rCBF) techniques, (3) so-called "split-field" methods and (4) lateral transfer of training. Each technique will be briefly mentioned below.

Electroencephalography (EEG) involves the recording of electrical potentials by electrodes on the scalp or in the brain. Physiological techniques such as EEG or measurement of evoked potentials may be used on normal subjects in order to

monitor differences in electrical activity in both cerebral hemispheres simultaneously in a non-invasive manner. The major criticism of this approach is that while recording may be done at high speeds, resulting in good temporal resolution, the spatial resolution of the electrical activity can be very limited, making accurate localization of activity within a hemisphere difficult. In contrast, methods involving glucose metabolism or regional cerebral blood flow, which generally involve injecting a radioisotope and observing patterns of either metabolic activity or blood flow within the brain, are limited by poor temporal resolution. That is, the summation of activity may take up to several minutes during which time the psychological processes of the subject have certainly changed (see Springer & Deutsch, 1993, for a more detailed review).

Methods for investigating interhemispheric collaboration using split-field presentation of modality-specific stimuli include: (1) visual half-field (tachistoscopic) presentation of visual stimuli (e.g., Kimura & Durnford, 1974); (2) dichaptic presentation of tactile stimuli (e.g., Witelson, 1976); and, (3) dichotic listening (e.g., Kimura, 1964). Generally, these studies incorporate some measure of response reaction time or accuracy, and compare scores for unilateral versus bilateral presentations of stimuli. Inferences may then be made regarding the degree of interhemispheric collaboration based on performance on this measure of laterality.

Of these methods, the visual half-field technique is probably the most popular. Here visual stimuli are presented to one or both visual fields and compared for speed of identification. Observations may then be made regarding the advantage of unilateral (one visual field) versus bilateral (both visual fields) presentation to assess the extent of interhemispheric collaboration for a variety of visual stimuli.

There are technical and other problems associated with the visual half-field method, however (Cook, 1986). Within a few milliseconds after presentation of a stimulus to one visual field, both eyes naturally realign on the stimulus, sending the information to both hemispheres. For this reason, extremely brief (less than 100 msec) presentation times must be used. Although this rapid presentation produces unilateral stimulation, it places severe limitations on the complexity of stimuli that may be used and presents problems of ecological validity. This is an obvious disadvantage when attempting to study higher cognitive processes. More importantly, the perceptual half-field techniques were initially developed as a means of reducing hemispheric interaction and studying each hemisphere in isolation in order to investigate differences in function, not hemispheric collaboration. For these reasons alternative non-invasive methods of measuring interhemispheric collaboration are necessary in order to look at the issue of transfer of information.

One such method is the lateral transfer of training paradigm. This method is particularly useful because it allows for the free flow of information between the hemispheres, as opposed to attempts (for example, when t-scope or dichotic listening methods are used) to restrict input and processing to one hemisphere or the other in isolation. The transfer of training method restricts input to one hemisphere, and output to one hemisphere, but does not restrict processing in between. The details of how this is done will be described in the next section.

Lateral Transfer of Training

As noted previously, practicing a skill such as inverted-reversed printing with one hand typically facilitates subsequent performance by the opposite untrained hand. This phenomenon, known as "lateral transfer of training", provides the basis for an important alternative method for investigating interhemispheric communication in the brain (Parlow & Kinsbourne, 1989). By examining directional effects of transfer (typically one hand benefits from opposite-hand training more than the other), inferences can be made regarding the nature of interhemispheric collaboration for a particular skill.

In very early studies, the term "cross-education" was used to describe the transfer of a skilled act from one side of the body to another (e.g., Davis, 1898, cited in Woodworth, 1938). More recently, this term switched to "lateral transfer of training". In the most general sense, transfer is defined as the extent to which

"experience or performance on one task influences performance on some subsequent task" (Ellis, 1965, p. 3). Lateral transfer then, can be seen as one example of transfer of learning, one which involves transfer of learning between limbs on opposite sides of the body (Parlow, 1983).

Lateral transfer will be assumed to have taken place when prior opposite limb training affects the acquisition, performance or relearning of a task by an untrained limb. In this context, learning will be inferred from the observation of stable performance changes accompanying practice, and which include a reduction in errors and/or general improvement in performance.

Transfer of training from left to right hands and from right to left hands has been observed for a variety of manual tasks (see review by Bray, 1928). Many of these studies showed directional effects, finding more transfer from one hand to the other than vice versa (e.g., Davis, cited in Bray, 1928; Ewert, 1926).

Several different explanations have been proposed to account for transfer of training between hands. In 1903, Woodworth (cited in Bray, 1928) proposed the "Theory of Identical Elements" which suggested that transfer occurs from one hand to the other when the subject learns task-specific "part-activities" common to both. Similarly, Judd's "Theory of Generalization" (1908) emphasized cognitive "generalizations" that are learned by the trained part of the body and applied in the performance of the untrained parts. It is still not clear whether identical elements

or general methods play a greater role in the magnitude of lateral transfer of training. Bray (1928) suggested that these theories are complementary and can, in fact, be combined as a "Theory of Common Elements". Another possibility was advanced by Davis (cited in Bray, 1928), who suggested that transfer may occur from trained to untrained hand through direct (but covert) training of the unpracticed hand by the spread of neural impulses during training to the motor centers controlling the unpracticed hand.

Methodological complexities probably contributed to the decline in interest in lateral transfer. These problems will be discussed in the next section.

Methodological Issues

Variations in experimental design are common in this literature, and present a considerable challenge when comparing the results of different studies. Both between-subject and within-subject designs were criticized early on, particularly in relation to their ability to demonstrate directional effects (see review by Bray, 1928).

The most commonly used design in the earliest studies depended on pre-testing the limb under study. This procedure was followed by opposite limb practice, and then by a second test of the relevant limb. By subtracting the pre-test score from performance at test, a measure of the benefit of the intervening practice was obtained. Ewert (1926) pointed out that this design failed to take account of the

fact that the performance of novel skills typically improves dramatically during the first few trials of practice. The pre-test may therefore have accounted for a large part of the improvement observed.

Many complex designs were developed to circumvent this problem. However, the addition of control groups is cumbersome, and requires the use of a large number of subjects. An example follows (see Table 1). This design permits the experimenter to subtract the effect of pre-testing from the effect of lateral transfer.

Group 1:(RLR): Pre-test right hand, Train left hand, Test right hand.

Group 2 (LRL): Pre-test left hand, Train right hand, Test left hand.

Group 3 (RL): Rest, Train right hand, Test left hand

Group 4 (LR): Rest, Train left hand, Test right hand

Table 1 An example of a within-subject design.

A between-subject design which avoids this problem was first described by Cook (1933, cited in Parlow, 1983, p. 14). This design is simpler, as it requires only two groups, one where half the subjects shift from right hand to left hand performance (RL) and the rest shift in the opposite direction (LR), (see Table 2).

Performance on the first practice trial of Group 1 can be compared with that of the test trial of Group 2, and vice versa.

Group 1 (RL): Train right hand, Test left hand.

Group 2 (LR): Train left hand, Test right hand.

Table 2 An example of a between-subject design.

Some designs have directly compared the performance of the two hands (right and left) at test. In this instance, there is the possibility of baseline hand differences in performance and unequal rates of learning between hands. That is, the limbs studied may not be equivalent in skill, and may not necessarily learn at similar rates (Parlow, 1983). This highlights the necessity to include same-hand training control groups for comparison.

Hicks (1974) and more recently, Parlow and Kinsbourne (1989, 1990) have utilized a design which incorporates same-hand training control groups (e.g., RR and LL groups) for comparison purposes. This enables a comparison to be made between the amount of transfer seen after opposite-hand training with the amount of transfer that is seen after same-hand training (see Table 3).

Group 1 (LR): Train left hand, Test right hand.

Group 2 (LL): Train left hand, Test left hand.

Group 3 (RL): Train right hand, Test left hand.

Group 4 (RR): Train right hand, Test right hand.

Table 3 An example of a between-subject design allowing for the comparison of opposite-hand and same-hand transfer of training.

This is a between-subject design where opposite-hand training is assessed relative to a group receiving an equal amount of practice but using the same hand.

The latter is assumed to represent maximal transfer possible for that hand.

Parlow and Kinsbourne (1989) argued that this comparison of opposite-hand training with the optimum performance of the same-hand (i.e., following same-hand training) is fundamental to the accurate measurement of transfer of training. This design also controls for different rates of learning that may exist between the hands. For example, it allows the researcher to compare the left hand performance after same- and after opposite-hand training, and does not need to contrast the left and right hands directly to each other. This is important, as the rate of learning likely to be slower for the left hand, at least in right-handers. This design was the

one chosen for the present study.

Measurement of Transfer

The measurement of transfer may be made in several ways (see review by Gagné, Forster & Crowley, 1948). For a thorough review of measurement issues pertaining to transfer of training, the reader is referred to Ellis (1965).

To date, there appears to be no consensus as to how lateral transfer should be measured. This lack of agreement makes it difficult to compare different studies. To determine whether transfer has occurred we need to consider what was measured and how it was calculated. The comparisons employed, the task studied and the design used all affect the meaningfulness of transfer scores.

One criticism emphasized by Ammons (1958), has to do with the problem of using an equal interval scale for the study of motor skill acquisition. He noted that motor skill does not typically improve on a linear basis. For example, Ammons noted that a gain which amounts to 5% of maximum performance may be far more difficult to achieve when the starting point is 0% than when performance is already at the 50% level. Similarly, while a 50% improvement in performance for a beginner may only be slightly noticeable (as he or she is still making a lot of errors), a 1% gain for an expert may be considerable.

In the following section, other factors which may play a role in transfer will be discussed.

Other Factors Influencing Transfer

With respect to the transfer of training paradigm, one consideration is whether there is an impact of the (rest) interval between trials as well as in the interval that separates practice and test trials. Such intervals are important in reducing the so-called "work" variables, including "work decrement" and fatigue. These refer to a temporary lowering of performance seen early in training on continuous tasks (Parlow, 1983). The role of these functions in transfer of training is not clearly established. Some authors (e.g., Ammons, 1958) have reported that dissipation of work decrement (or "reminiscence") can cross from one limb to another. For example, Ammons (1958) observed that performance of a second (untrained) limb in rotary pursuit was considerably better after a 20 minute rest when compared to performance after only a 20 second one. Archer and Bourne (1956) concluded that 30 seconds is sufficient between trials for reminiscence (recovery) to take place. Ammons (1947) concluded that the dissipation of inhibitory effects reaches an asymptote after approximately 5 minutes.

It is not known whether there are directional effects for this phenomenon. This factor is controlled (but not eliminated) in the present thesis by using a constant (2 minute) rest interval between training and test trials and a discrete training procedure with 15 second intervals between each trial during the training phase.

The Inverted-Reversed Printing Task

The task used in the present investigation involves printing a sequence of alphabet letters in a new orientation (i.e., upside down and backwards). This skill is relatively unfamiliar and is used because it is considered by some researchers (e.g., Hicks, 1974; Meier & French, 1965; Parlow, 1983; Parlow & Kinsbourne, 1989) to be a novel variant of the very familiar printing skill which forms the basis of hand preference.

Although some aspects of the inverted-reversed printing task could be considered as lateralized to the left hemisphere (e.g., motor/sequential and/or verbal), the fact that the letters have to be spatially displaced and mentally rotated (generally considered to be a right hemispheric component) make this task relatively hard to lateralize in terms of popular characterizations of hemispheric specialization. Therefore, this task is perhaps best characterized as not highly lateralized, although it is typically associated with a strong right hand superiority for both speed and accuracy in right-handed subjects. It is likely that, with practice, the spatial component is reduced, as the task becomes automatized.

Directionality and Early Models of Transfer

Early researchers (e.g., Hicks, 1974; Meier & French, 1965) found lateral transfer for the inverted-reversed printing task to be asymmetrical, with the right hand benefiting more than the left hand from opposite-hand training. In these

studies, subjects practiced printing the uppercase letters of the alphabet (A through Z) in inverted-reversed orientation for 10-15 trials before test performance. To explain their findings, these researchers made reference to the popular "callosal access" model of interhemispheric communication (refer to page 2 in the present manuscript), whereby the direction of greater transfer of training is linked with the absolute specialization of the left hemisphere in manual skills. According to this model, the right hand has direct access to skills learned by the left hand (and stored in the left hemisphere) whereas the left hand has only indirect access across the corpus callosum to skills learned by the right hand (also stored in the left hemisphere).

Alternatively, Parlow and Kinsbourne (1989) argued that transfer of training for the inverted-reversed printing task was greater in the right to left direction. Subjects in their study, as in the earlier studies, practiced printing for 10 trials before completing 10 test trials. These researchers suggested that the directional effect they observed may be linked to the greater proficiency of the left hemisphere/right hand for a language based task and concluded that there is greater transfer from the dominant to non-dominant hemisphere than vice versa. Although Parlow and Kinsbourne's (1989) results were found to be generally compatible with their "proficiency model", problems were noted by these researchers which argued against prior proficiency being involved in the mediation

of transfer. To account for these discrepancies, a third model was proposed, called the "cross-activation" model. According to this model, training of the hand contralateral to the hemisphere which is specialized for a particular skill (the dominant hemisphere) may lead to the formation of dual "engrams" or internal representations by a process they called "co-activation". This prepares the non-dominant hemisphere and leaves it in a state of readiness to respond. In contrast, training of the hand contralateral to the non-dominant hemisphere leads to the formation of only a single engram within that hemisphere, and no co-activation occurs. This model implies three things: (1) the processing advantage of one hemisphere over the other is linked to the direction of greater transfer of training, (2) the direction of greater transfer can reverse depending upon the nature of the task (which may employ processes for which either hemisphere is specialized), and (3) transfer is greater when dual (independent) engrams are formed in parallel during training than when a single engram is formed and subsequently "transformed" to the other hemisphere at a later time (see Parlow and Dewey, 1991; for more information).

A fourth explanation for the asymmetry of transfer of training was also considered, that the level of familiarity with the task (i.e., a low number of training trials vs. a high number of training trials) may be a critical factor in terms of affecting transfer of learning between hands. As noted in an earlier section of this

paper (p. 17), Goldberg and Costa (1981) proposed that familiarity may be relevant to the study of skill acquisition. According to their model, the right hemisphere may be specialized for processing newly acquired "novel" tasks and the left hemisphere for a task that has been well routinized or "well learned". This model suggests that the characteristics influencing transfer are related to the degree of novelty of the material to the subject. Parlow and Kinsbourne's (1989) results could be interpreted as support for the idea that there is greater transfer from right to left hand (from left hemisphere to the right) when the task is a highly practiced one, like handwriting. Work on asymmetrical transfer of braille acquisition by the same authors (Parlow & Kinsbourne, 1990) showed the reverse to be true, with greater transfer from left hand to right hand, for this more unfamiliar task, which also lends support to the "familiarity" model. If the right hemisphere is more important at the early stage of processing novel stimuli, these studies would together support the view that hemispheric specialization is linked to the directional effects and that lateral transfer is greater when one trains the specialized hemisphere.

To order to test the "familiarity" model, Semeniuk (1992) varied the number of practice trials in her study as subjects practiced the inverted-reversed printing task. Semeniuk found that the direction of greater transfer reversed with greater practice. At a low level of training (12 practice trials), transfer of training was

found to favour the right hand, whereas at a high level of training (22 practice trials) transfer favoured the left hand. She argued that this reflected a shift in the relative contributions of right and left hemisphere as the printing skill became well-learned. This finding is compatible with both the Goldberg and Costa (1981) model of hemispheric specialization and the cross-activation model of interhemispheric communication proposed by Parlow and Kinsbourne (1989). More specifically, Semeniuk suggested that the Goldberg and Costa model of hemispheric specialization may be viewed as an extension of the cross-activation model by specifically addressing the issue of task novelty as an important factor underlying hemispheric reversal.

Unfortunately, Semeniuk's (1992) data is not available. The present study is required to provide some closure for the important issue of familiarity and directional effects in lateral transfer for the inverted-reversed printing task. In order to replicate the latter finding, it is necessary to systematically vary the number of training trials as subjects practice the inverted-reversed printing task, and see if the direction of greater transfer reverses with greater practice.

In Experiment 1, of the present investigation, the number of training trials needed to establish two levels of training (e.g., low or "unfamiliar" vs. high or "familiar") was determined. This was done by asking subjects to "overlearn" the task using either the right or the left hand. Several criteria were used to establish

the cut-off points: (1) when does a plateau start and end in the learning curve, and (2) when do they reach a performance floor for errors? This experiment addressed the question, when is the task “novel” and when is it “familiar”? In Experiment 2, a between-subjects design was used to assess lateral transfer of training while the task was still unfamiliar and after it became overlearned. This study included same-hand as well as opposite-hand training groups. Subjects received a low or a high level of practice. It was predicted that asymmetrical transfer of training would be observed at the low level of training (favouring the right hand) and that the direction of greater transfer would reverse at the higher level of training (favouring the left hand). This would support both the model proposed by Goldberg and Costa (1981) and the cross-activation theory of Parlow and Kinsbourne (1989) and indicate that an integrative theory of interhemispheric communication should take into consideration both task familiarity and hemispheric specialization to accounts for directional effects.

Experiment 1

Method

Subjects. Twenty right-handed university students obtained from the introductory psychology pool served as participants. Half the subjects were male and the other half female. They ranged in age from 18 yrs, 2 mos to 29 yrs, 2 mos ($M = 21$ yrs, 6 mos; $SD = 2$ yrs, 4 mos). Handedness was assessed by administering the

Edinburgh Handedness Inventory (EHI; Oldfield, 1971, APPENDIX A). Only strongly right-handed subjects (EHI scores $\geq 70\%$) were used. One subject did not meet the handedness criterion and was excluded from the final sample.

Materials. A sequence of twelve upper-case letters consisting of the letters "BJLNRSDFGPQZ" were printed on a 2" X 6" (5.1 cm X 15.2 cm) card. These letters did not form a word and were selected because they are specifically demanding in terms of their rotational requirements (e.g., some letters like "o" were not included). Subjects were provided with two sheets of white unruled paper (27.6 X 21.3 cm) and an HB pencil. The trials were timed using an electronic timer (Lafayette Instrument co., model 58010) connected to an auxiliary relay (model 58013) and repeat cycle timer (model 51013).

Design and Procedure. After completing a consent form, the Edinburgh Handedness Inventory, and a General Background Questionnaire (see APPENDIX A), subjects were asked to print a series of letters in inverted-reversed orientation (i.e., upside down and backwards) with either their right or left hand. Each subject was presented with the sequence of 12 upper case letters on a card, and told that these letters did not form a word. They were instructed to print them on a sheet of paper with the HB pencil from the lower right corner of the page to the left, and from the bottom of the page to the top. The card was placed directly in front the subjects at midline. To clarify the instructions, the experimenter first demonstrated

how the letters "ABC" would look in this novel orientation. Subjects were told to print as rapidly as possible while trying not to make mistakes. Each trial was 30s in length and the beginning and end of each trial was indicated by a tone from the electronic timer. At the end of each trial, small timing marks (two slashes) were made by the experimenter. Upon completion of each trial, subjects were given a 15s interval between trials during which the paper was turned 180° to provide them with visual feedback on their performance. Subjects were not allowed to correct or change their output during or between trials. The next trial started after the last letter completed (i.e., they did not start at "B" each trial - this was in order to prevent the subjects from copying their preceding work). All of the subjects completed 24 trials in this fashion, in 2 blocks of 12 trials. A 2 min. rest between blocks was provided to reduce the effects of fatigue. During the rest interval the experimenter verbally obtained information to complete the experimental credit receipt (name, 49.100 section, student ID number).

Subjects were pseudo-randomly assigned so that half the subjects printed with the left hand, half the right. Two dependent measures were recorded for each trial, the number of letters printed in the correct orientation (NCL) and the number of letters printed incorrectly (NIL). These dependent variables were chosen to facilitate comparison with earlier studies (e.g., Parlow and Kinsbourne, 1989). Letters were considered to be correct as long as they were printed in the correct

orientation and recognizable. Letters oriented more than 45° from upright were considered to be incorrect. If for any reason a subject printed a letter incorrectly and subsequently (against instructions) corrected it while the trial was in progress, the letter was scored as one error as well as one correct. If they printed a letter after a trial was over, the letter was not counted. The percentage of letters incorrectly printed was calculated using the formula $Y = 100 * \text{letters incorrect} / (\text{letters incorrect} + \text{letters correct})$ to provide a measure of accuracy independent of speed.

Results

Right and left hand acquisition curves (letters correct and percentage incorrect) are illustrated in Figure 1 and 2. Due to the absence of a gender effect, the data were collapsed across males and females for presentation here.

Figures 1 and 2 show that, although left hand performance was poorer than right, the pattern of performance was similar for right and left hands. For example, in terms of the mean letters correct, Figure 1 reveals a large increment in performance from trials 1 to 10 for both hands. Between trials 10 and 15, the slope has reduced substantially, indicating a decline in the rate of improvement. By trial 19, a plateau in performance is evident.

With respect to errors, Figure 2 demonstrates a rapid initial increase in accuracy for both hands between trials 1 and 8. Between trials 9 and 15, there is a

Fig. 1. Right hand(a) and left hand(b) acquisition curves for the number of letters correct on each trial in Experiment 1.

Fig. 2. Right (a) and left (b) hand acquisition curves for the percentage of letters incorrectly printed for each trial in Experiment 1.

reduction in the slope. By trial 17, mean accuracy was 100%. This pattern was observed for both the right and the left hand.

Discussion

The results of Experiment 1 indicated that there were natural transition points in the acquisition of the inverted-reversed printing skill. Visual inspection of the means suggested that for our purposes, this task may be considered to be "novel" following 8 trials and "well-learned" after 18. These are the training intervals that were selected to be used for Experiment 2

Experiment 2

Hypotheses

Experiment 2 was designed to test the following three hypotheses:

Hypothesis 1 : Same-hand transfer of training will be superior to opposite-hand transfer for both right and left hands at all levels of training (i.e., $RR > LR$, $LL > RL$).

Hypothesis 2 : Transfer of training will be asymmetrical at both levels of training (8 and 18 trials).

Hypothesis 3 : The asymmetry of transfer observed for the inverted-reversed printing task will favour the right hand at low levels of training and the left at high levels. This last result would be compatible with both the Goldberg and Costa (1981) model of hemispheric specialization and the cross-activation model of

interhemispheric communication proposed by Parlow and Kinsbourne (1989).

Method

Subjects

Sixty-four undergraduates (32 males and 32 females) participated for credit from the introductory psychology pool. They ranged in age from 18 yrs, 0 mos to 30 yrs, 0 mos ($M = 20$ yrs 8 mo; $SD = 2.0$ yrs). Handedness was assessed by administering the Edinburgh Handedness Inventory (EHI; Oldfield, 1971, APPENDIX A). Only strongly right-handed subjects (again using the criterion, $EHI \geq 70\%$) were used. Three subjects were tested but had to be excluded from the sample. One of them did not meet the handedness criterion. Another did not understand the instructions and was not able to print any of the letters in the appropriate orientation. One subject confided that they were told about the experiment and had spent time practicing the task.

Design

Subjects were assigned to the experimental and control groups in a semi-random manner to ensure an even representation of males and females in each group. There were 4 experimental and 4 control groups (see Table 4) with 8 subjects in each group. Participants in the experimental groups (numbered 1-4 below) used either their left or right hand for the practice trials and the opposite untrained hand at test (designated RL or LR, where the first and the second letter

refer to the hands used for the practice and test trials respectively). Those in the control groups (5-8) used the same-hand for both practice and test trials (i.e., RR or LL). Performance at test was evaluated following either 8 or 18 practice trials. In all groups, 2 test trials were completed after an interval of 2 minutes. The procedure and materials for the printing task is described below.

Insert Table 4 About Here

Materials

The same as in Experiment 1.

Procedure

The procedure was the same as in Experiment 1, except that subjects in the experimental groups (1-4) used the opposite-hand for the two test trials (i.e., subjects in RL will switch from right to left at this point and subjects in LR will switch from left to right), while those in the control groups (5-8) used the same-hand as in the practice trials (i.e., RR or LL). In addition, a third dependent measure, percentage transfer, was calculated for subjects in the four hand training groups (i.e., RL level 1 and 2, LR level 1 and 2) using the formula shown in Table 6.

Experimental and Control Groups for Letter Task

Group No.	Practice Hand	No. of Practice Trials	Test Hand
Experimental Groups (Opposite Hand Training)			
1	R	8	L
2	R	18	L
3	L	8	R
4	L	18	R
Control Groups (Same Hand Training)			
5	R	8	R
6	R	18	R
7	L	8	L
8	L	18	L

Results

There were four independent variables in this experiment: hand used at test (right or left), level of training (level 1 = 8 trials, level 2 = 18 trials), gender (male, female), and type of training (type = same-hand, opposite-hand). To reduce the likelihood of falsely rejecting the null hypothesis, power is reported for all non-significant effects that pertain directly to the hypothesis.

Preliminary Analyses

In order to determine whether there were baseline hand differences in the acquisition of the inverted-reversed printing skill, and to ensure that the groups were comparable before the test trials, trials 1-8 were examined for all 16 groups. A $2 \times 2 \times 2 \times 2 \times 8$ mixed analysis of variance was performed to assess the effects of First Hand (right or left), Type of Training, Level, Gender and Trials (1-8), with the latter the only within-subjects factor. The resulting analysis revealed no main effect of Gender, $F(1, 48) < 1$, $p = .902$, and this variable did not interact with any other variables. Subsequently, this variable was dropped, and the data was collapsed across males and females (see Fig. 3 and 4). This analysis revealed a main effect for First Hand, $F(1, 56) = 9.50$, $p < .01$, and Trials, $F(7, 392) = 53.21$, $p < .01$, and a First Hand $\times$ Trials interaction, $F(7, 392) = 3.28$, $p < .01$. As expected, the right hand produced more correct letters ($M = 13.05$, $SD = 3.15$) than the left hand ($M = 10.60$, $SD = 3.57$) during the first 8 acquisition trials, and

performance improved with practice for both hands (see Fig. 3). As well, the slope for the right hand was higher than for the left hand.

The analysis was repeated using the error data. This analysis again revealed a main effect of Trials, $F(7, 392) = 4.06$, $p < .01$, as performance improved across trials for both right and left hands. No other main effects or interactions were significant in this analysis.

For the purpose of examining the acquisition of the inverted-reversed printing skill at the two levels of practice for each hand separately, practice trial data (collapsed across gender) for each group is presented in Figures 3 and 4. These data illustrate the learning curves across practice, based on number correct and percentage error, for each hand. In this way, the effect of additional same-hand practice on performance as well as hand differences can be seen. These findings clearly demonstrate that learning is occurring with this inverted-reversed printing procedure. Hand differences were apparent during the practice trials. A right hand advantage in terms of NCL was observed throughout. In contrast to the right hand, performance of the left hand showed a relatively low error rate initially.

These analyses confirmed that Type of Training and Level did not play a role prior to the test trials. In other words, the experimental and control groups were comparable before the test trials. As well, they showed that there was a hand difference (favouring the right hand) in letters correct but not in the error data

Fig. 3. Right hand (a) and left hand (b) acquisition curves for the number of letters correct on each practice trial in Experiment 2.

Fig. 4. Right hand (a) and left hand (b) acquisition curves for the percentage of letters incorrectly printed on each practice trial in Experiment 2.

during training.

Test Trials

Test performance (averaged across 2 trials) was evaluated with the use of a 2 (Test Hand) x 2 (Type of Training) x 2 (Level) x 2 (Gender) between-subject analysis of variance. Because the number of incorrectly printed letters was extremely low in level 2 ($\underline{M} = .45$, $\underline{SD} = .63$), the error data were not analyzed.

As expected, right hand scores at test were superior to left hand scores, and this hand difference was observed at both levels of practice. In addition, visual inspection of the means suggested that same hand training was superior to opposite hand training in all the conditions.

The results of the analysis confirmed the presence of a main effect of Type of Training, $\underline{F}(1,63) = 15.16$, $p < .01$, confirming that same hand training ($\underline{M} = 18.17$, $\underline{SD} = 4.03$) was superior to opposite hand training ($\underline{M} = 13.92$, $\underline{SD} = 3.27$). Also, the main effect of Test Hand, $\underline{F}(1,63) = 14.28$, $p < .01$, was significant. As expected, performance with the right hand ($\underline{M} = 18.10$, $\underline{SD} = 5.1$) was superior to that of the left hand ($\underline{M} = 13.98$, $\underline{SD} = 4.0$). The expected interaction of Level, Type and Test Hand did not approach statistical significance however, $\underline{F}(1,48) = 0.01$, $p = .909$ (power = .038). In addition, there were no main effects of Level, $\underline{F}(1,48) = 3.36$, $p = .073$ (power = .434), or Gender, $\underline{F}(1,48) = .00$, $p = .955$. In the absence of a gender effect, the data were collapsed across males and females

for presentation here. The cell means and standard deviations for NCL are presented for each group in Table 5 (see Appendix B) and are illustrated in Figures 5 and 6.

A second ANOVA was performed dropping Gender from the analysis, as the preceding analyses suggested it played no role. The results of this analysis again failed to reveal the expected interaction of Level, Type and Test Hand, $F(1, 56) = .03$, $p = .870$ (power = .040). No other interactions were significant in this analysis. Again, the main effects of Test Hand, $F(1,63) = 15.66$, $p < .01$, and Type of Training, $F(1,63) = 16.62$, $p < .01$, were significant. In addition, a main effect of Level was revealed, $F(1,56) = 3.68$, $p < .05$. Subjects' performance was better at level 2 ($M = 17.05$, $SD = 5.37$), than at level 1 ($M = 15.05$, $SD = 4.60$), indicating the expected effect of increased practice on the acquisition of this printing task.

In order to provide a measure of accuracy independent of speed, a new dependent measure, percentage of letters incorrect, was calculated. This dependent measure was obtained by dividing the average number of errors for each subject (across the two test trials) by the sum of the average number of correct letters for each subject (across the two test trials) plus the average number of errors (across the two test trials), expressed as a percentage (see Figure 7). A third ANOVA was performed using Type, Level and Test hand as independent

* $p < .05$

Fig.5. Mean number of correctly printed letters on practice and test trials as a function of hand and type of training at two levels of training.

Fig. 6. Mean letters correctly printed in Experiment 2, at levels 1 and 2, as a function of trial and group.

Fig. 7. Percentage of letters incorrect in Experiment 2, at levels 1 and 2, as a function of trial and group.

variables. The results of this analysis revealed no interactions. Again, the three-way interaction was not significant, $F(1,56) = .01$, $p = .924$ (power = .037). Once again, the main effect of Level reached significance $F(1,56) = 10.09$, $p < .01$, demonstrating that performance in level 2 was better than in level 1. Subjects in level 2, made fewer errors ($M = 2.79\%$, $SD = 3.92\%$) than those in level 1 ($M = 8.00\%$, $SD = 8.12\%$). In fact, after 9 training trials, the percentage of letters incorrect decreased rapidly. Subjects finally reached a floor for errors at 17 trials. This floor effect was due to the fact that the average number of incorrectly printed letters was extremely low after 18 practice trials ($M = .453$, $SD = .63$).

Planned Comparisons

Planned comparisons were also conducted to examine hypothesis 3. One-tailed t-tests were used. Comparisons of the test scores (averaged across 2 trials) at level 1 for groups RR ($M = 19.31$, $SD = 3.22$) and LR ($M = 14.31$, $SD = 1.93$) revealed a significant difference, $t(7) = -3.34$, $p < .05$. This was not true for groups LL ($M = 15.00$, $SD = 5.22$) and RL ($M = 11.56$, $SD = 3.09$), $t(7) = 1.36$, $p = .217$ (power = .287). Thus, the expected directional effects were not found at level 1; same and opposite-hand training were found to be comparable for the left hand at this level of training (groups LL 8 and RL 8), but for the right hand they were not comparable. At level 2, there was a significant difference between the type of training for the right hand (group RR, $M = 22.06$, $SD = 5.16$ and group

LR, $\underline{M} = 17.00$, $\underline{SD} = 5.55$), $t(7) = -1.84$, $p < .05$, and for the left hand, (group LL, $\underline{M} = 16.56$, $\underline{SD} = 2.50$ and group RL, $\underline{M} = 12.81$, $\underline{SD} = 2.52$), $t(7) = 4.38$, $p < .01$. In other words, same and opposite-hand training groups were not comparable for the right hand (groups RR and LR), or for the left hand (groups LL and RL) at this level.

Additional Analyses

Transfer Due to Opposite-Hand Training

A second method for investigating Hypothesis 2 and 3 was used to analyse the data by calculating percentage transfer scores (or gain) for each of the RL and LR groups, relative to the corresponding same-hand training groups. The advantage of this method is that it takes into account differences in performance for each hand and allows for the direct comparison of the two hands.

Percentage transfer scores were calculated for subjects in the four experimental groups (i.e., RL at levels 1 and 2, LR at levels 1 and 2), using the formula in Table 6. This score was based on performance at test divided by the average score at test for the comparable same-hand training group (i.e., after a comparable number of practice trials) expressed as a percentage of the latter. Therefore, this score represents the improvement in performance after opposite-hand training relative to maximum improvement (100%) expected for that hand. The performance of subjects in RL groups were compared to LL groups. Subjects in LR groups were

compared to RR groups. In Table 6, the equations that were used for calculating left and right hand scores, as well as the same-hand mean scores used as the denominator in these calculations is presented.

Insert Table 6 About Here

Here the "Y" represents an individual's test score. For example, in the first case, an individual in group RL, level 1, with a hypothetical test score of 10.0 letters correct would receive an overall score of 100% because that is the maximum score expected for someone using the left hand after 8 practice trials (assuming that maximal performance can be estimated from the average performance of the LL group who received this amount of training). The mean score determined for each hand and level of training is graphically illustrated in Figure 8.

Gain scores for subjects using the right hand after opposite-hand training averaged 74.1% (SD = 10.02%) and 77% (SD = 25.45%) for levels 1 and 2 respectively, compared to 77.1% (SD = 20.64) and 77.4% (SD = 15.23%) for subjects using the left hand.

A 2 x 2 ANOVA was performed on the gain scores to examine the contributions of test hand (L or R) and level of training (low vs. high). No interactions or main effects were observed in this analysis. In particular, the

Calculation of Percentage Transfer Scores for Groups RL and LR only

Level 1 = 8 trials

Level 2 = 18 trials

Group	Level	Aver. RR or LL	% Transfer
RL	1	10.0 (for LL)	$\frac{Y = \text{Test Score } (X_{RL})}{10.0} \times 100$
LR	1	15.2 (for RR)	$\frac{Y = \text{Test Score } (X_{LR})}{15.2} \times 100$
RL	2	18.3 (for LL)	$\frac{Y = \text{Test Score } (X_{RL})}{18.3} \times 100$
LR	2	20.6 (for RR)	$\frac{Y = \text{Test Score } (X_{LR})}{20.6} \times 100$

Fig. 8. Percentage of transfer for groups RL and LR as a function of level of training and hand used at test.

interaction of Level x Hand did not yield statistical significance, $F(1,31) = .06$, $p = .804$ (power = .048). However, visual inspection of the means suggested that transfer favoured the left hand at level 1 ($M = 77.1\%$, $SD = 20.64\%$), and that this asymmetry disappeared at level 2.

Inter-trial Correlations

In Parlow and Kinsbourne's (1989) study, correlations between the last practice trial and initial test trials were investigated. This was done in order to test the assumption underlying the proficiency model, that greater proficiency on the last practice trial should be associated with greater proficiency on the initial test trial, regardless of the direction of transfer. They looked at the opposite-hand training groups and reported that a high correlation between these trials was associated with poor transfer, whereas a low correlation was found to be associated with good transfer.

A pattern similar to the one found by Parlow and Kinsbourne (1989) was found for opposite-hand training groups in the present study for level 2 (see Table 7, Appendix B). That is, at level 2, a high inter-trial correlation was observed for group LR, Pearson $r(8) = .94$, $p < .01$ and, a low inter-trial correlation was observed for the group RL, Pearson $r(8) = .49$, $p = .221$. As expected, the correlations calculated for level 1 and 2 were high for the group RR, Pearson $r(8) = .88$, and $.93$, respectively, $p < .01$, as well as for group LL, Pearson $r(8) = .98$,

and .84, $p < .01$.

When the pattern for level 1 was examined, the inter-trial correlation for group RL was relatively low, Pearson $r(8) = .73$, $p < .05$, as was that of group LR, Pearson $r(8) = .63$, $p = .09$. Similar inter-trial correlations were reported by Semeniuk (1992) for groups LR at levels 1 and 2 (see Table 7). Therefore, if this correlation is compared with an estimate of transfer (from the planned comparisons reported above) for each group, it appears that in different cases, a high correlation was observed in association with low transfer (e.g., group LR at level 2), a low correlation with good transfer (e.g., group RL at level 1), and low correlations with low transfer (e.g., both in group LR at level 1, and group RL at level 2).

General Discussion

Recall that three hypotheses were investigated in this thesis. Hypothesis 1 predicted that same-hand transfer would be superior to opposite-hand transfer for both right and left hands at all levels of training (i.e., $RR > LR$, $LL > RL$). The second hypothesis predicted that the direction of transfer of training would be asymmetrical at both levels of training (8 and 18 trials). Hypothesis 3 predicted that the direction of the asymmetry of transfer observed for the inverted-reversed printing task would favour the right hand at low levels of training and the left at high levels. This last result would be compatible with both the Goldberg and Costa (1981) model of hemispheric specialization and the cross-activation model

of interhemispheric communication proposed by Parlow and Kinsbourne (1989). Specifically, it had been suggested by Semeniuk (1992) that the Goldberg and Costa model might be viewed as an extension of the cross-activation model by specifically addressing the issue of task novelty as an important factor underlying hemispheric reversal.

The results of the present investigation supported Hypothesis 1 and (partially) Hypothesis 2. Same-hand groups were superior to opposite-hand training groups (produced more correct letters) at both levels, and asymmetrical transfer was observed at level 1, although not at level 2. However, the data failed to support the shift in direction of transfer predicted in Hypothesis 3. In fact, the results of the planned comparisons revealed greater transfer from right to left hand at level 1, the opposite of what was predicted. Specifically, performance after opposite-hand training in group RL was as good as that of group LL suggesting complete transfer of training from the right hand to the left. In contrast, the performance of subjects in group LR was significantly lower than for those in group RR at level 1, indicating incomplete transfer to the right hand. At level 2, the performance of subjects in group LR was significantly lower than for those in group RR and performance of subjects in group RL was significantly lower than for those in group LL. When the percentage of opposite-hand transfer was calculated and compared across hands, the graph confirmed this pattern: transfer favoured the left

hand at level 1, while no hand difference in transfer gain was observed at level 2.

The fact that there is greater transfer from right hand to the left hand at level 1 was surprising, given the results of Experiment 1. In that experiment, it appeared that this task was still novel after 8 training trials. However, the finding replicates the findings of Parlow and Kinsbourne (1989). They examined lateral transfer of training after 10 trials, and reported greater transfer from the right to the left hand than vice versa. This finding does not support the integrative model of hemispheric specialization proposed by Semeniuk (1992). It may be that because the skill investigated is based on printing, subjects even in level 1 are not truly unfamiliar with the task. That is, subjects in level 1 may be processing the task in a manner similar to that of a “well-learned” one despite the non-alphabetic sequence, and the inversional and rotational demands of the task, and despite the observation in Experiment 1. Therefore, we may be comparing two levels of “familiar” in this study (well-learned vs. overlearned), and not two distinct levels of familiarity (i.e., novel vs. well-learned). Perhaps to ensure that the task is really novel, non-English speaking subjects unfamiliar with our script, or pre-schoolers might be used. It may also be necessary to look at very early trials for a task such as this (e.g., 4-6 trials). Semeniuk (1992) reported that there was no asymmetry of transfer for the inverted-reversed printing task after 2 trials, but this finding has yet to be replicated. Subsequent research may develop better ways to statistically determine

the most appropriate intervals.

Perhaps another task might be more appropriate, which is more truly unfamiliar, such as reading braille, a tactile alphabet that bears no resemblance to standard script (cf., Parlow and Kinsbourne, 1990). A future researcher might want to see whether the expected pattern (greater transfer from left to right hand) would be observed in sighted subjects (unfamiliar with reading braille) tested using that task and the design employed in the present investigation. By contrast, if familiarity plays a role, blind (experienced) braille readers should behave similarly to the subjects in the present investigation. The fact that Parlow and Kinsbourne found greater transfer from left to right hand in sighted subjects learning braille lends support to this suggestion.

What about gender? It should be noted that the lack of a gender effect found in the present study supports the findings of previous research (e.g., Parlow & Kinsbourne, 1989). This is surprising, due to the mental rotational demands of the inverted-reversed printing task and literature that suggests males score higher than females at tasks involving spatial abilities (Bradshaw, 1989). Therefore, caution should be exercised before a conclusion can be drawn from the findings of the present investigation. In the future, this gender issue needs to be addressed by using more subjects in each cell, for all experimental and control groups.

Insight into the processes controlling the acquisition and transfer of a skill such as inverted-reversed printing may be gained by examination of between hand inter-trial correlations. In the present study, inter-trial correlations revealed a low correlation for group LR at level 1 (see Table 7). This was somewhat unexpected. This group also demonstrated low transfer of training. Subjects in this left hand group may have been processing the task as an unfamiliar one. Although the asymmetry of transfer at level 1 was similar to that observed by Parlow and Kinsbourne (1989), the moderately high inter-trial correlations between the right and left hands (group RL) suggested that the subjects may have been processing the task as a well-learned one. The reason for the high performance (as indicated by the mean transfer gain) and the moderately high correlation for this group may be due to the fact that subjects receiving 8 training trials were in the tail-end portion of the novice period where they were beginning to improve their performance for this task (producing more correct letters with lower percentage error). Perhaps choosing a point earlier in this stage (say, after 3 or 4 trials) might have altered the results. The relatively low correlation found for this group after 18 training trials is compatible with the low correlation between hands in the RL group found in Parlow and Kinsbourne's study. As well, intertrial correlations for the both opposite-hand training groups (LR and RL) at level 2 were similar to those found by Parlow and Kinsbourne (1989).

What do the correlations tell us about the underlying processes in the brain?

First, relatively low correlations between trials immediately before and after switching hands have been found for group RL at 8, 10, 18 and 22 trials in the present thesis and across a number of studies (cf., Parlow & Kinsbourne, 1989; Semeniuk, 1992, Hicks, 1974). This finding is compatible with Parlow and Kinsbourne's idea of dissimilar underlying processes (e.g., dual engrams) being formed by this group. The present findings however, cast doubt on the relationship between engrams and transfer that was suggested by these authors. Parlow and Kinsbourne proposed that greater transfer between the hands was associated with lower correlations between the hands, suggesting that dissimilar underlying processes (e.g., dual independent "engrams" in each hemisphere) would facilitate the transfer of skill between hands, while poor transfer was associated with higher correlations suggesting similar underlying processes (e.g., sharing of a single engram). In the case of the novice and the expert, one might propose that those who are unfamiliar with the skill differ from the more experienced, not in the way predicted by this study, but in the nature of the relationship between the performance means and the correlations. Speculating on the mechanisms by which interhemispheric transfer takes place, the low transfer and low intertrial correlations for group LR at level 1 may be linked to the formation of independent engrams in the novice, one in each hemisphere. In this case, it may be that the first

engram (formed in the right hemisphere by the left hand) is inadequate for the other (left) hemisphere to use, resulting in poor transfer (to the right hand). Eventually as the task becomes well learned, the second engram reaches a stage of development where it can subsequently be used by the right hand, as evidenced by a higher correlation for group LR at level 2. This possibility needs further study, before a coherent theory can be proposed.

So what can we conclude from these data? First, the asymmetry at level 1 supported the cross-activation model proposed by Parlow and Kinsbourne (1989). In contrast, at level 2 there was no hand difference in transfer of training, a result that is not compatible with their model. These findings fail to replicate the direction of transfer predicted by Semeniuk's (1992) integrative model. It may be that during the initial acquisition phase with the preferred (right) hand, there is greater transfer from the right hand (and dominant left hemisphere) to left hand (and nondominant right hemisphere) for a printing task such as this. This asymmetry may vanish as the task became automatized and overlearned. At this time, this hypothesis needs further explicit experimentation, possibly using another task, such as reading braille.

Second, the specific mechanisms by which engrams are formed and how this relates to inter-trial correlations and transfer of skill from one hand to another remains unclear. Given the low power of the non-significant comparison at level 1

(between group RL and LL), this finding will have to be confirmed by future studies with a larger sample size. In addition, imaging technologies, such as glucose metabolism scanning or regional cerebral blood flow (rCBF) techniques, monitored throughout task performance, might be useful in the future to help clarify how or whether the issue of task novelty affects asymmetrical transfer of training.

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APPENDIX A

EDINBURGH HANDEDNESS INVENTORY

Surname _____ Given Names _____
 Date of Birth _____ Sex _____

Please indicate your preferences in the use of hands in the following activities by putting + 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 ++. If in any case you are really indifferent put + in both columns.

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

Please try to answer all the questions, and only leave a blank if you have no experience at all of 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)		
i	Which foot do you prefer to kick with?		
ii	Which eye do you use when using only one?		

L.O.

Leave these spaces blank

DECILE:

General Background Information Questionnaire

Name _____
 Gender: M F
 Telephone _____

Date of Birth _____
 Today's Date _____

1. Do you consider yourself a) right-handed, b) left-handed, or c) ambidextrous?

2. Circle the hand (L=left, R=right, B=both) which you prefer to use for each of the following activities:

- L R B a) write?
- L R B b) draw?
- L R B c) remove the top card of a deck of cards (dealing)?
- L R B d) use a bottle opener?
- L R B d) throw a baseball to hit a target?
- L R B e) use a hammer?
- L R B f) use a toothbrush?
- L R B g) use an eraser on paper?
- L R B h) use a tennis racket?
- L R B i) use scissors?
- L R B j) hold a match when striking it?
- L R B k) stir a liquid or semi-solid?
- L R B l) on which shoulder do you rest a bat before swinging?
- L R B m) with which foot do you kick a ball?

3. Consider the four pictures below. Which looks most like the way you hold your hand when writing? (mark the box under it).

4. For each blood-relative, indicate handedness (circle):

Father = Right-handed? Left-handed? Don't know.
 Mother = Right-handed? Left-handed? Don't know.

How many left-handed brothers do you have? ____.
 How many left-handed sisters do you have? ____.
 How many right-handed brothers? ____.
 How many right-handed sisters? ____.

Other left-handed relatives? Specify their relationship to you (e.g. mother's brother).

5. Do you believe that you have or had in the past a learning disability? If so, in what area? Circle as many answers as are appropriate.

- a) No
- b) Yes, in Reading
- c) Yes, in Math
- d) Yes, in Spelling
- e) Yes, in _____

6. Have you ever been identified by a qualified professional as having a learning disability?

- a) No
- b) Yes, by a School Psychologist
- c) Yes, by a Clinical Psychologist outside of the school system
- d) Yes, by a medical doctor
- e) other _____

If yes, at what age? _____

7. Medical History:

a) Have you ever had a head injury, seizures or other neurological problems? _____

b) Any serious injury to fingers, left or right hand or back? _____

c) Do you have any hearing problems? (if yes, specify which ear) _____

8. Personal History:

a) What is your first language? _____
Do you speak any other languages fluently? _____

b) Do you play a musical instrument or sing? _____

Rate your ability and circle your choice below:

None Novice Intermed Expert
1 2 3 4

c) Rate your typing ability and circle your choice:

None Novice Intermed Expert

APPENDIX B

Table 5

**Mean Letters Correctly Printed and Standard Deviations for Each Group as a
Function of Hand Used at Test, Type of Training and Level**

Hand Used at Test:		Right(R)			Left(L)		
Type of Training:		No training (R)	Same hand (R)	Opposite hand (L)	No training (L)	Same hand (L)	Opposite hand (R)
Level 1	<u>M</u>	10.71	19.31	14.31	8.75	15.00	11.56
	<u>SD</u>	1.18	3.22	1.93	.78	5.22	3.09
Level 2	<u>M</u>	9.88	22.06	17.00	9.00	16.56	12.81
	<u>SD</u>	1.04	5.16	5.55	1.01	2.50	2.52

Table 7

**Inter-trial Correlations Between Last Practice Trial and First Test Trial in
Experiment 2 as a Function of Group and Training Trials**

	Group			
	RR	LR	RL	LL
Dubé (1997)				
8 Trials	.88*	.63	.73*	.98
18 Trials	.93*	.94*	.49	.84*
Parlow and Kinsbourne (1989)				
10 Trials	.84*	.86*	.21	.94*
Semeniuk (1992)				
12 Trials		.74*	.81*	
22 Trials		.88*	.16	

*p<.05