Effects of Handedness on Completion Time during Performance of Multiple Tasks Using “Proper” and “Improper” Tools

Lisnnette M. Nieves Suarez
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EFFECTS OF HANDEDNESS ON COMPLETION TIME DURING PERFORMANCE
OF MULTIPLE TASKS USING “PROPER” AND “IMPROPER” TOOLS

by

Lisnette M. Nieves Suarez

A Thesis Submitted to the Department of Human Factors & Systems in Partial
Fulfillment of the Requirements for the Degree of Master of Science in Human Factors
and Systems

Embry-Riddle Aeronautical University
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This thesis was prepared under the direction of the candidate’s thesis committee chair, Dennis A. Vincenzi, Ph.D., Department of Human Factors & Systems, and has been approved by the members of the thesis committee. It was submitted to the Department of Human Factors & Systems and has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Human Factors & Systems.

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Wish you all the best in life!
ABSTRACT

Handedness is a very critical factor involving single or multiple tasks that are designed for a specific hand. The purpose of this research was to investigate the effect of proper tool design. This research identified the dominant hand and measured task completion time between each of two tasks, 1) the use of left and right-handed scissors using the right hand, and 2) Mouse Manipulation Task using the calculator provided by the computer with a left and right-handed mouse using the right hand. Annett’s (1995) 12-item questionnaire was used to identify the preferred hand. This questionnaire consisted of having the participants answer questions about performance on a number of habitual acts in which the roles of the right and left hand are sharply distinguished.

Does the completion time of specific tasks differ across left and right-handed people when using “proper” and “improper” tools? The hypothesis stated that the task completion time between the preferred hand with “proper” and “improper” tools would be different. The justification for this study was the lack of knowledge that many individuals have with regard to the problem of handedness while performing manual tasks in industry, education, and everyday life. The conclusions of these experiments have implications for industrial and aerospace performance of left and right-handed individuals.

Selection of operators for industrial, aerospace, mail distribution, domestic tasks, and school tasks, as well as many other tasks, may be dependent on handedness of the person, particularly when machines are designed for a specific hand. If lefthanders are confronted with tools and workstations which are disadvantageous for them, negative effects on work performance, work satisfaction, and work safety may be experienced.
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CHAPTER I
INTRODUCTION

Handedness

Various aspects of Paleolithic art have been cited as evidence for the evolution of handedness (Pobiner, 1999). For example, most prehistoric handprints are of the right hand, while painted hand silhouettes are usually of the left hand, suggesting that they were drawn with the right (Pobiner, 1999). In addition, most of the paintings of human and animal heads found in caves are facing left, and it is assumed that, since modern right-handed artists draw profiles this way, earlier hominids did also (Pobiner, 1999).

Some “natural” human behaviors commonly observed can easily differentiate between the two sides of the body. Some examples are shaking hands with the right hand, making pledges of allegiance and oaths of office with the right hand, and saluting with the right hand and arm. Religious gestures are normally right-handed, as when making the sign of the cross, and most people write with their right hand. Many people are also right-footed, for example, individuals will tend to kick a football with the right foot.

But, what do the terms “left” and “right” mean? Several dictionaries describe “left” as the wrong way, awkward, fatigued, and defective. The same dictionaries describe “right” as correct and skillful. Webster’s Third International Dictionary lists several
definitions of the adjective left-handed, including the following (Deutsch & Springer, 1989):

- marked by clumsiness or ineptitude, awkward
- exhibiting deviousness or indirection oblique, unintended
- given to malevolent scheming or contriving sinister, underhand

Why do many people develop preferences with the left hand rather than the right hand? Scientific research has attempted to explain why people are left-handed and what is the cause of their delay in performance while working on different tasks. One reason given in the past for left-handedness was "emotional negativism." A general distrust of left-handedness probably reached a peak in the ideas of Cesare Lomboroso, an Italian psychiatrist and criminologist (Brown, 1979). Brown theorizes that there were to be found more left-handers than usual in prison. He argued that left-handedness tended to be a sign of the born criminal. Gardner, as cited in Brown (1979), points out, these views are discredited in today's society. However, Gardner goes on to make an interesting point about the possible conflict that could have developed between a strongly left-handed child, not forced to use his right hand, and the child's parents at a time when left-handedness was at best frowned upon. Brown (1979) quotes *The Times* of August 10, 1976:

"Recent study comparing left and right-handed 11 year olds from a large national sample of the population showed considerable and significant differences between teacher's reports on left-handers and the results of objective tests. Teachers reported a greater tendency amongst left-handed pupils towards poor control of their hands, "bad writing" and speech, which was "difficult to understand." Subsequent tests showed the differences to be unfounded.

The article also points out that these problems are understandable because of the "odd" position that left-handed people tend to write. Brain damage has been offered as an explanation for a minute instance of left-handedness. Some research shows that there may
be slightly more left-handers than right-handers who suffer from undetected brain damage (Brown, 1979) Another explanation for left-handedness is that the individual has not inherited the usual right-handed bias. An observation that can be made is as follows: "there tends to be two types of left-handers those that write with the hand in the same type of position as a right-hander and those who write with their hands in hook style" (Brown, 1979) Brown suggests that left-handers who adopt the hook style may have language functions represented primarily in the left hemisphere, while individuals who do not may have language localized mainly in the right. Individuals who used more relaxed writing position tended to have speech more localized in the right hemisphere. However, this observation awaits further testing Brown (1979), also points out that some teaching methods for children attempt to enhance the right hemisphere thinking in order to increase performance.

The Human Brain

The human brain is divided into two halves, which are almost physically symmetrical. The cerebral cortex forms the upper surface of the brain. The two halves (or hemispheres) of the cerebral cortex are joined together by the corpus callosum, made up of some 200 million nerve fibers (Brown, 1979). The right side of the cortex is largely responsible for the control of the left side of the body, and vice versa. The left hemisphere is predominantly involved with analytic thinking, especially language and logic. This hemisphere seems to process information in an ordered sequence, which is necessary for logical thought since logic depends on both sequence and order (Brown,
Certain psychologists argue that each hemisphere is geared to the particular type of thinking or cognitive style, the left geared toward an analytical, logical mode for which words are an excellent tool. The left hemisphere seems to process information in a serial manner, one bit of information after another. Understanding speech involves an analysis of words in a serial manner. The left brain also deals with information in an analytical and sequential way and in a comparative and referential manner (Haseltine, 1999). The right hemisphere is primarily responsible for our orientation in space, artistic talents, bodily awareness, and recognition of faces (Haseltine, 1999). The right cerebral hemisphere does a better job than the left in reading facial expressions, decoding tone of voice in speech, and comprehending the big picture in visual, auditory, and tactile stimuli (Haseltine, 1999). It processes information more diffusely than the left hemisphere does and integrates material in a simultaneous, rather than a linear fashion. The right hemisphere in most adults shows itself to be superior at depth, image, pattern, and face perception. It is highly involved in pitch perception. Some researchers describe the right hemisphere as more creative. When given a word it tends to produce an association less common than that produced by the left hemisphere. Images, an often-encountered feature in creative thinking, have also been associated with the right hemisphere. It has been argued that when very strong imagery is used in speech, the images will tend to be processed by the right hemisphere. The right hemisphere has also been associated with dreaming (Brown, 1979). One reason for this is that dreams are usually highly image ridden and creative as opposed to analytical and verbal. There have also been reports of people with damage to the right hemisphere who have claimed to have stopped dreaming.
A convergent type of thinking seems to epitomize the left hemisphere while more divergent thinking characterizes the right (Brown, 1979). Whereas the left hemisphere tends to process information serially, one bit after another, the right hemisphere is geared to the processing of parallel information, dealing with several bits of information at the same time. In 90% of the human population, the left hemisphere houses the control center for speech function (Bodary & Miller, 2000). Stacks, as cited in Bodary & Miller (2000), suggested that the left hemisphere (right-handed) appears highly rule-governed, logical, and analytical. The right hemisphere is involved in non-symbolic and frequent, highly intense messages (Bodary & Miller, 2000). Right hemisphere messages are more emotional, less rational and do not confirm easily to linear patterns of sequential processing (Bodary & Miller, 2000). There are numerous explanations regarding the cause of this seemingly random pattern of right hemisphere dominance, and most explanations involve both genetic and environmental issues (Bodary & Miller, 2000). Geschwind and Galaburd, as cited in Bodary & Miller (2000), speculated that most people are genetically programmed to be left-hemisphere dominant for language and handedness, although environmental influences such as birth stress can alter this programming. Annett, as cited in Bodary & Miller (2000), suggested that left-handedness, right-hemisphere dominance, may also be genetically determined in some instances, for example when left-handedness is consistent across several generations of a particular family. Imagination, which is used better by the rightist (left-handed people use their right hemisphere), can also be used in what would normally be considered a leftist (right-handed people use their left hemisphere) thinking task (Brown, 1979). This creative thinking enhances information.
recall, and creates outstanding images in the brain Deutsch & Springer (1989), referring to studies that compare the performance of left-handers and right-handers on tests of higher mental functions have yielded little in the way of data to support predictions of inferior performance by left-handers A recent review of the literature cited 14 studies examining reading ability Only one of them found a difference between left-handers and right-handers, and it reported that left-handers were superior in performance Using measures of academic achievement, one study found no difference between groups, whereas another study reported that left-handers performed worse on college entrance examinations Three studies reported that left-handers performed worse in perceptual tasks, although the sole study to be replicated failed to show a difference in subsequent work Despite this relatively meager collection of empirical evidence documenting performance differences between left-handers and right-handers, the association of left-handedness with deficit persists (Deutsch & Springer, 1989)

Occasional studies have reported superior performance by the left-hander, but these studies did not paint anymore clear a picture than those pointing to deficits in left-handers (Deutsch & Springer, 1989) Proponents are eager to mention that Leonardo da Vinci, Benjamin Franklin, and Michelangelo were left-handed (Deutsch & Springer, 1989) The predominance of right-handers has created a tendency to use only the right hand in several texts and TV programs Until the latest crew change in Star Trek set matters right, even the androids in science fiction were universally right-handed (Aldersey-Williams, 1999) A string of the terms exist to label or insult left-handers, and in many languages, including our own, the very terms “left” and “right” are loaded with multiple meaning
(Aldersey-Williams, 1999) Although many inconclusive and confounded studies have been performed in relation to left and right-handedness, the issue of statistical differences in cognitive functioning and handedness will continue to be pursued because of its significance to theories of brain variability and organization (Aldersey-Williams, 1999).

In a study performed by Martin & Jones (1999), with the assumption that cognitive processes are independent of handedness, the results supported the hypothesis that the effect is a consequence of differences between handedness groups in terms of specific patterns of underlying motor activation rather than in terms of more general differences in function between cerebral hemispheres.

Alony (1998) studied the aspects of handedness in cognitive and affective variables. The issue of whether differences exist between right-handed and left-handed people in cognition and emotion was addressed in two studies. The first study was conducted with 974 right-handed and 108 left-handed Israeli school children between the ages of 8 and 11 years old. The test battery included cognitive and affective measures: The MEM Questionnaire, The Coloured Progressive Matrices, and The Standard Progressive Matrices evaluated cognition. The Self-Concept Scale, The Anxiety Scale, The Intellectual Achievement Responsibility Questionnaire, and the Intrinsic-Extrinsic Motivational Questionnaire assessed affective ability. Although these results may provide answers to current questions, one likely source of conflict between researchers in relation to validity is the lack of agreement on the measurement of handedness. There is no gold standard for handedness determination (Peters, 1998). This means that there is not a perfect measuring technique that can help in determining handedness. Data on
school achievement and teachers’ evaluation of children’s mental, emotional, and social skills were also collected. The results demonstrated no significant differences between right and left-handed children on any performance tasks in either domain (Alony, 1998). Left-handed children showed similar capabilities on higher order verbal and non-verbal thinking and resembled the right-handed groups in the affective domain (Alony, 1998). They showed the same level of anxiety, and obtained the same scores on self-concept, motivation, and locus of control (Alony, 1998). The findings also suggested the existence of stronger associations between Syllogism and Categorization, and non-verbal cognitive processing, and between cognition and emotion in the left as compared to the right-handed children (Alony, 1998). Teachers also evaluated the left-handed children as having significantly lower social skills. The second study focused on perception of emotion on chimeric faces (faces with half-sad, half-happy configuration). The sample consisted of 48 university students and computer workers, 21 right-handers and 21 left-handers, and 6 switched-handed participants. Data were collected on manual activity, and participants were presented booklets with pictures of chimeric faces and their mirror images. They were asked to judge which of the faces seem to be happier. Findings showed significant differences between right and left-handed participants in their perceptual biases. Right-handed participants judged the left positive configuration as happier and the left-handed participants judged the right positive configuration as the happier one. The sum of the results seems to indicate that differences in self-organization might exist between right and left-handed individuals (Alony, 1998).
The neuroscience and psychiatric literature abounds with conflicting reports as to whether handedness is related to brain asymmetries, overall size of brain structure, or various psychiatric disorders (Peters, 1998). Jaynes, as cited in Brown (1979), suggests that there may be a relationship between schizophrenia and right-hemispheric activities. He also argues the following points:

“Firstly, whereas most of us show in total a slightly more left hemispherical activity than right, the reverse is observed in schizophrenia patients. A schizophrenic shows a slightly more activity in the right hemisphere. Whereas the non-schizophrenic tends to switch to and from between the hemispheres about once a minute, switching in schizophrenics only occurs about once every four minutes. This suggests that schizophrenics tend to get stuck on one hemisphere or the other and so cannot shift from one mode of information processing to another as fast as the rest of us (p. 61).”

Some research also points out that while only 10 to 20% of the population is left-handed, 15% or more of epileptics and mental defectives are left-handed (Brown, 1979). Mental defects in handedness can also be measured. A study by Steenhuis & Bryden (1999) had mentally retarded participants and a normal control group. This experiment compared mentally retarded participants with normal control participants that had no sinistrality record. It has also been documented that handedness items can be classified into skilled and unskilled activities (Steenhuis & Bryden, 1999). The Waterloo Handedness Questionnaire was also utilized when experimenting with mentally retarded patients. It has been a questionnaire mostly used by Steenhuis & Bryden (1999) and Bryden, Singh, Steenhuis & Clarkson (1994). In this study, they used this questionnaire with skilled and unskilled items. For example, for the skilled items they used the following: write, draw, hammer, use scissors, use a toothbrush, strike a match, swing a racquet, throw spear, comb, throw ball, and, for the unskilled items the following were used: pick up paper, hit, carry a suitcase, and flip a coin. This questionnaire also has a 5
point scale (5 always right, 4 right usually, 3 equal, 2 left usually, 1 left always). For each item, participants' actual performance was observed five times. Mentally retarded participants performed these tasks for an eight-month period. The tasks were randomized before the experiment. Although the mentally retarded participants performed for eight months, the normal control group performed only once and indicated their hand preference for each one of the tasks on a 5-point scale. Because of a concordance rate of over 95% between hand preference and performance, and earlier evidence that these two measures of handedness were highly correlated, normal control, participants' judgment on the preference questionnaire was considered an index of handedness. In the results, it was observed that mentally retarded compared to normal control participants, were mixed-handed. This was evident by a shift in their mean response toward the mid-point (3 equal) of the hand-preference scale (Mandal, Pandey, Tulsi Das & Bryden, 1998). One may also ask why the mentally retarded participants did not show a leftward bias. As the present study focused on those mentally retarded participants who had a negative history of parental sinistrality (left-handers in family history), they predicted that the incidence of left-handedness would be less than in other samples.

Is Handedness Hereditary?

Is handedness, like eye color, blood type, and general body build, genetically determined? The probability of two right-handed parents having a left-handed child is 0.02 (Deutsch & Springer, 1989). It rises to 0.17 if one parent is left-handed and to 0.46 if both are left-handed (Deutsch & Springer, 1989). These figures are consistent with the
hypothesis that genes play a role in determining handedness (Deutsch & Springer, 1989).

Nature and nurture are confounded in these figures, making it very difficult to sort out the contribution of each

Advantages and Disadvantages of Handedness

Many of these explanations give rise to answers that many of us thought were not possible. However, most of these explanations give rise to doubts that seem illogical to humans. Human limitations should be taken into consideration when explaining a natural behavior that is presented before birth and develops during their maturity. Some advantages and disadvantages exist of left-handedness in a world that is primarily geared for right-handed people. For example, there are problems with scissors, irons, and potato-peelers. In order to account for the difference between right and left-handers, there are left-handed moustache cups and a shop for left-handers in London (Brown, 1979). Many of the reasons why left-handed people have difficulty while performing tasks is due to the lack of support from designers and engineers. Left-handers continually have to get used to the technology that is designed for their non-predominant hand. Left-handedness has an effect on individual work strain (Schmauder, Eckert & Schindhelm, 1992). An unfavorable design of workplaces, machines, tools, and devices increases the strain on the worker and affects safety.

Although the left-hander may not find life as convenient as the right-hander, many left-handers are noted to be more ambidextrous than right-handers (Martin & Jones,
Such ambidextrous ability is obviously an advantage in sports and in manipulative tasks like surgery and playing a musical instrument.

What are the consequences for individual human beings who are left-handed or right-handed? Martin & Jones (1999) note the implications in two respects. At the manual performance level itself, of course, differences are commonplace (for example, scissors tend to be designed to accommodate primarily right-handed use). McManus & Bryden (1993), as cited in Martin & Jones (1999), noted that the degree of lateralization of language function within the cerebral hemisphere differs between the left-handed and right-handed populations. Martin & Jones (1999) also pointed out that there is much evidence of the involvement of implicit motor activity relating to the limbs in rehearsal, because concurrent movement of the limbs reliably interferes with retention. Although many have stated that handedness affects cognitive abilities, Martin & Jones (1999) state that the relationship between handedness and the operation of cognitive processes have not been correlated with any established effects of handedness on cognition at all. Martin & Jones (1999), also point out that the hypothesis of a wider association of left-handedness and reading disorder with various forms of immune disease has proven difficult to sustain.

Inverted and Non-inverted Hand Postures

The research of Levy and Reid, as cited in Deutsch & Springer (1989), has identified another variable that may help sort left-handers into different groups based on brain organization. Some left-handers write in an inverted or hooked position, holding the
pen or pencil above the line of writing (Figure 1). Other left-handers, as well as almost all right-handers, hold their writing instruments below the line of writing. Levy and Reid also argued that the position of the hand provides useful information about which hemisphere is controlling speech and language in an individual. Their view is in conflict with conventional wisdom, which suggests that hand posture is due only to training.

According to the conventional view, some left-handers, encouraged to position their writing paper in the same way as right-handers, have adopted the hooked posture out of necessity. Without it, their hand hides most of what they have just written.

In contrast, Levy and Reid argued that the inverted hand posture means that the speech hemisphere is ipsilateral to the preferred hand. Thus, the speech of a left-handed inverter would be controlled by the left hemisphere (Deutsch & Springer, 1989). The speech of a right-handed inverter would be controlled by the right-hemisphere (Deutsch & Springer, 1989). The speech of non-inverted writers would be controlled by the hemisphere opposite to the preferred hand (Deutsch & Springer, 1989). On verbal trials, participants were asked to identify a syllable (See Figure 2). On dot trials, they were to remember the position of a dot and locate it a few seconds later on a matrix of boxes displayed in free vision.
Figure 1 Non-Inverted and Inverted Writing Postures of Left-Handers (Deutsch & Springer, 1989)

Part A of Figure 2 shows that non-inverted right-handers and inverted left-handers were most accurate when the syllable task appeared in the right field and the dot task appeared in the left. Part B of Figure 2 shows non-inverted left-handers and inverted right-handers were most accurate when the syllable task appeared in the left field and the dot task appeared in the right. Visual-field asymmetries in accuracy (measured as the number correct in the right field minus the number correct in the left field) were computed for each type of stimulus to provide a measure of hemispheric asymmetry for verbal and spatial processing. The results clearly indicate that right-handers who use the non-inverted hand posture show right visual field superiority for syllables and a left visual superiority for the spatial task. Left-handers who write with the non-inverted posture show the reverse. In contrast, left-handers with a non-inverted posture perform like the
right-handers with a non-inverted posture. The sole right-hander who wrote with an inverted posture generated data compared with those of left-handers writing in a non-inverted fashion.

Figure 2: Syllable Identification and Dot Location Tasks. (Deutsch & Springer, 1989).

These results suggest that it is possible to tell about brain organization from an individual's handedness alone. Like most interesting findings, they raise more questions than they answer. Deutsch & Springer (1989) refer to a study using elementary school children. It was found that the closer the child's writing posture was to an upright position, the better the child's reading ability.

Deutsch & Springer (1989) stated that both of these studies point to the existence of a relationship between hand posture and asymmetry in the processing of printed
language, rather than more general hemisphere asymmetries, and highlight the importance of not treating language as a unitary process

Simple Tests When Identifying Hand Preference and Society

According to Brown (1979), various researchers have stated that between one and 30% of the world may be left-handed. He also points out that between 5 and 12 percent of the population either are, or consider themselves to be, left-handed. Various types of analysis can help identify the hand that is more predominant in an individual. For example, writing, drawing, striking a match, sweeping with a broom, taking a lid off a box, using a knife, using a spoon, using scissors, brushing teeth and throwing. Additionally, Brown (1979) also states that the environment or non-environment encourages handedness. Some researchers argue that environmental factors have encouraged or even determined the right-hand dominance. Many societies have worshipped the sun and to follow the path of the sun in the Northern Hemisphere the body moves from left to right. And, a very clear association has been made between the sun, the life giver, and the right side of the body and the right hand (Brown, 1979). One major objection of this theory is that the right hand is and has been dominant in the Australian hemisphere. Brown (1979), also explains the "sword and shield" theory.

"the choice of the right hand as the preferred one might have been dictated by the fact that the heart is displaced slightly to the left so that the left hand was assigned the passive, protective role of holding the shield while the right hand wielded the stick or sword (p 15)."

One argument, taken from Brown (1979), stresses that many skills only need one hand. It is therefore not surprising that one hand has developed slight dominance over the
other. While the left hand holds, the right hand operates. An individual who truly prefers a particular hand will use that hand to carry out unimanual activities in a variety of different situations, even when it is uncomfortable or awkward to do so (Bryden, Singh, Steenhuis, & Clarkson, 1994). A strong right-hander will contort him/herself into every odd position in order to be able to drive a nail by holding a hammer in the right hand.

Many other researchers suggest that handedness, at least right-handedness, is genetically based (non-environment). Signs of handedness have been observed from birth. Children who later become right-handed have been observed to have a definite pattern of handedness in the first year of life. Such a pattern is difficult to explain as an environmental product (Brown, 1979). Harris, as cited in Martin & Jones (1999), documented the social forces that, particularly in the past, have tended in many cultures to convert some individuals from acting with the left hand to acting with the right hand, and showed that these forces have been particularly active in the areas of writing and eating. In a study performed by Roy (1996) males and females reported if they were pressured to change hand preference. From a sample of 596 participants, 71 males and 147 females reported pressure. 121 participants over the age of 41 reported pressure and 97 participants over the age of 41 reported pressure. McNeilage et al., as cited in Martin & Jones (1999), proposed the existence of a general primate tendency toward a posture of left-hand specialization for reaching and right-hand specialization for manipulation. Subsequent research has provided some support for population level hand preferences in primates, although not necessarily consistent with this scheme (Martin & Jones, 1999). For example, Diamond and McGrew, as cited in Martin & Jones (1999), reported entirely
right-hand preferences for eight different activities in cotton-top tamarins, whereas Laska, as cited in Martin & Jones (1999), reported entirely left-handed preferences for three different activities in spider monkeys. Nevertheless, the issue of primate handedness provides an important evolutionary perspective on human handedness, indeed, it has been proposed that human motor planning in general is based on evaluating stored posture representations (Martin & Jones, 1999). Calvert & Bishop (1998) when quantifying hand preference, observed that the interaction with the environment in extrapersonal space may be a key factor contributing to manual dominance, and that the lateralization of fine motor skills interacts with this attention bias.

Observations of the eye used to thread a needle, and eavesdroppers when listening with the right ear, have helped in distinguishing the side of the brain that many people use. In addition, many of these behaviors may also be attributed to environmental factors that have made a left-handed person eavesdrop with their right ear, or even thread a needle using their right eye. Societal pressure directly results in switching hand preference among innately left-handed people and may also decrease the overall prevalence or reported innate left-handedness (Galobardes, Bernstein & Morabia, 1999). Other explanations for handedness include anatomical differences between the two halves of the brain and vascular supply to these two halves. Other theories consider fetal position, birth order and brain damage (Brown, 1979).
Other Handedness Comparative Studies

Hoffman (1997) performed a study of five experiments in which strongly lateralized participants performed movement tasks with their preferred and non-preferred hands. These tasks were ballistic movements, Fitt’s task, pin-to-hole transfer, Drury tracking task, and a modified form of the Drury tracking task in which participants cut paper with scissors. Very little work has compared the performance of these two groups when using their preferred and non-preferred hands (Hoffman, 1997). Few studies have used tasks that are quantifiable in their difficulty (Hoffman, 1997). It has been suggested that performance differences are due to information-processing capabilities of the left and right hemisphere (Hoffman, 1997). Hoffman has also noticed that when visual control is required, the preferred hand will perform better. Bryden, Singh, Steenhuis & Clarkson (1994) also stated that all tasks show significant differences between handedness groups, indicating that all of the hand performance measures are related to handedness as determined either by a questionnaire or by stated preference. Peters (1990), as cited in Hoffman (1997), reported that these interpretations are not always clear as there are occasions on which the non-preferred hand performs better than the preferred hand. Independent of the factors that produce the differences in hand performance, the industrial engineer is interested in the magnitudes of the differences in performance in common tasks (Hoffman, 1997). Predetermined motion time systems have nothing to say about the effect of handedness or the effect of using the non-preferred hand in assembly work (Hoffman, 1997). Hoffman has cited several authors that have given the conclusions of right-handers performing better than left-handers, and learning on psychomotor tasks.
were also lower for left-handers than right-handers. However, several factors may affect these conclusions such as the type of questionnaire measurement, difficulty of the tasks, and the level of normality between the participants (level of brain damage, if any) used when performing the experiments.

There are some areas where performance has been studied and the reported superiority of right over left-handers when using their preferred hands has not been found (Hoffman, 1997). Schmauder et al. (1993), as cited in Hoffman (1997), found that hand/arm force production by left-handers is generally higher than for right-handers and have non-preferred hand performance similar to their preferred hand, unlike right-handers who are considerably weaker in the non-preferred hand. Their studies were based on the following question/hypothesis: are the values of static operational force of the human-arm systems, as documented in the literature and in the standard specifications (which were established without special regard to handedness), equally valid for right and left-handed individuals, and the left and right hand/arm system of each group? If differences in strength between the left and right arm are observed, are the differences independent on the position of the point where the force is applied and/or the direction in which the force is applied? The distribution of handedness preference had a J-curve (See Figure 3). Respectively, there are relatively few markedly lateralized left-handed individuals, a small number of ambidextrous individuals, and a large number of right-handed individuals. As can be seen from the illustration, the distribution of hand performance is a "normal distribution" curve displaced to the right. This means that there are generally few people who show a markedly greater performance with their left hand-arm system. Many people
perform similarly with both arms although the right side generally exhibits better performance (Schmauder, Eckert & Schindhelm, 1992) In their results, they noticed that left-handed people are not more efficient with their dominant hand-arm system than they are with their subdominant hand-arm system.

Figure 3: Hand Preference with an Increasing Number of Right-Handers and Hand Performance more efficient when using Right-Hand (Schmauder, Eckert, & Schindhelm, 1992)

Left-handed participants even achieved slightly greater maximum static operational forces when using their right hand/arm system. Almost identical forces in the right and left hand-arm system of left-handers is an obvious indication that the right-
handed oriented environment compels even strongly lateralized left-handers to train permanently with their right hand (Schmaudeer, Eckert & Schindhelm, 1992).

The Drury Tracking Task, that involves drawing around paths, showed no significant effect for either the right-hand (RH) or left-hand (LH), but there were main effects for preferred (P) hand and not preferred (NP) hand (Hoffman, 1997). For all conditions, the preferred hand was significantly faster than the left hand, while for the left-handed group, only for the most difficult conditions was there a significant difference between the preferred and non-preferred hands. In all cases the preferred hand was faster.

These results in measured time (MT) are in agreement with other experiments in that there is generally no difference between left- and right-handers when using their preferred hands, but when using their non-preferred hands, left-handers are generally better in performance (Hoffman, 1997).

The task that involved scissors cutting around circular paths (modified Drury tracking task), is similar to the drawing around paths task, but used matched left- and right-handed scissors to cut between a marked track. On the basis of the mean data, the times for both the right- and left-handed groups using their non-preferred hand was greater than that for the preferred hand. In summary, it can be said for tasks requiring visual control, the data were consistent in showing that there was no significant difference in performance of left and right-handers when using their preferred hands. Left-handers were generally better than right-handers when using their non-preferred hand, and performance with the preferred hand was always superior to that of the non-preferred hand (Hoffman, 1997). The major implication of this work is that it is not necessary to
make extra time allowances for the left-handed worker; however, it may be necessary, in order to have the same performance as a right-hander, for the workplace to be organized as a mirror image of that for the right-hander so that the preferred hand is used for the same elements of the task for each group of workers. If this can be arranged, the data suggests that the left-handed worker will perform at least as well as the right-hander (Hoffman, 1997).

Subtle effects emerge when the different responses are performed with different hands, so that the responses are mechanically compatible and have unique identities (Proctor & Reeve, 1990). For this situation, Proctor & Reeve also explained that one might expect that response-response compatibility effects could be related to intermanual interactions, which can be observed when movements are performed with both hands simultaneously. Proctor & Reeve made two-choice experiments in which the two responses were to be performed with the left or the right hand.

In all experiments, participants had to respond with the left hand when the left signal was presented and with the right hand when the right signal was presented. In the first set of experiments, reaction times for 16 conditions were studied. These conditions were generated by assigning all possible pairings of two responses out of four to the two hands; the four responses were tapping with the index finger or thumb and alternating with the index finger or thumb. Proctor & Reeve (1990) explain that when the assignment to the two hands involved different movements rather than same movements, (a) mean reaction-time was longer, (b) mean (individual) reaction-time variability was larger, and (c) frequency of choice errors (responses with the wrong hand) was smaller.
Proctor & Reeve (1990) also specified the assumptions of the movement-precuing technique, characteristics common to the response alternatives in a choice task are specified in advance of the response signal. Only characteristics that are unique to the signaled response have to be specified during the reaction-time interval. This assumption was called the advance-specification assumption (Proctor & Reeve, 1990). According to this assumption, reaction time is longer due to larger numbers of movement characteristics and how the alternatives differ. In terms of the movement-precuing rationale, the choice between the left and right hand is a process that is distinct from specification of the characteristics of the movement to be performed (Proctor & Reeve, 1990). It is hard to visualize why the accuracy of choice between hands should depend on whether characteristics of the movements assigned to the left and right hand are preprogrammed or not (Proctor & Reeve, 1990).

In contrast to choice error frequency, the frequency of execution errors was not consistently different between conditions with same and different movements assigned to the two hands. If the movement assigned to the two hands in the choice task differ in a characteristic that is independent with respect to the hands, simultaneous programming of both responses should be possible. Whenever a difference between the movements assigned to the two hands results in an increase of reaction-time (or task completion time), intermanual coupling (one hand depending on the other) with respect to this characteristic can be inferred (Proctor & Reeve, 1990). When no reaction-time increase is observed, it can be concluded that the two hands are independent with respect to that characteristic on which the two choice responses differ (Proctor & Reeve, 1990). The
purpose of all the experiments was to examine subtle response-response compatibility effects that can be observed in tasks in which rapid responses are to be performance with either the left or right hand (Proctor & Reeve, 1990) This view is supported, first, by supportive evidence for the continuity assumption, and second, by a general convergence of response-response compatibility effects with results on intermanual interactions obtained with other kind of tasks (Proctor & Reeve, 1990) With respect to motor-programming research, reaction time experiments should no longer be kept separate from physiological work on motor preparation or other behavioral data (Proctor & Reeve, 1990)

Corballis, as cited in Deutsch & Springer (1989), offered another explanation, which has two parts, first, the difference between the hands is not a structural one, the hands differ in function but not in form, second, right-handedness, appears to be a uniquely human trait, setting us apart from other animals Before considering more modern theories of handedness, it is important to consider how handedness is actually assessed We might assume that the best way to find out whether a given individual is a left or right-hander is simply to ask Unfortunately, this direct approach does not always work Few people use one hand exclusively for all unimanual activities, and simple self-classification does not indicate how someone weighed various activities when making the determination (Deutsch & Springer, 1989) Another approach is to ask people which hand they use for specific activities The researcher can then compute a handedness preference based on the same weighting scheme for everyone Is handedness better viewed as a dichotomous or a continuous variable? It has often been argued that the hand that a
person prefers to use for performing a task is to some extent a function of the task to be performed (Martin & Jones, 1999) Martin & Jones (1999) also state that such choices across tasks can be used to derive handedness measures with multiple values rather than merely two values. Bryden, McManus, and Bulman-Fleming, as cited in Martin & Jones (1999), argued strongly for using only two categories, left-handed and right-handed. They stated that dichotomous classification allows consistency to be achieved across different studies of handedness in a way that no other classificatory procedure does, because, there is in practice, no generally accepted, continuous measure of handedness (Martin & Jones, 1999).

Researchers state that right-handed individuals are more proficient at making clockwise movements than at making counterclockwise movements, left-handed individuals are just the opposite (Woodson, Tillman & Tillman, 1992) However, all people make clockwise movements better with the right hand and counterclockwise movements better with the left hand (Woodson, Tillman & Tillman, 1992).

Salvendy (1970), as cited in Hoffman & Halliday (1997), concluded that the learning and performance ability of left-handers in psychomotor tasks was inferior to right-handers. No significant difference between the performance and learning ability of left-handers in comparison to right-handers was found in either task (Hoffman & Halliday, 1997).

Lacreuse & Fragaszy (1999) studied left-handed preferences in capuchins (monkeys). They tested whether the presence or absence of visual cues and explorative demands affected the strength and/or direction of lateral hand bias. Left-hand preferences
in monkeys for tactile (haptic) discrimination have been taken to indicate that the right hemisphere is more involved than the left hemisphere in solving these tasks (Lacreuse & Fragaszy, 1997). Although the capuchins showed a left hand preference to perform the task, finer analysis of tactile exploratory procedures revealed no difference in the way the left and right hands explored the objects, nor in the efficiency with which each hand solved the task (Lacreuse & Fragaszy, 1997) (See Figure 4).

Hand preference is one of the most obvious expressions of brain lateralization in humans (Lacreuse & Fragaszy, 1997). Overall, the most consistent data provide support for a left-hand preference in prosimians, and a right-hand preference in chimpanzees, bonobos, and gorillas for a variety of tasks (Lacreuse & Fragaszy, 1997). Fagot and Vauclair (1991), as cited in Lacreuse & Fragaszy (1997), have reviewed the evidence that manual asymmetries are dependant upon the demands of the task. The authors distinguish conceptually between simple or familiar tasks, for which non-human primates do not necessarily exhibit population-level lateral biases, and complex or novel tasks, which are predicted to elicit population-level biases (Lacreuse & Fragaszy, 1997). Manual preference in humans is not a unilateral trait but depends on the cognitive and spatiotemporal requirements of the tasks (Lacreuse & Fragaszy, 1997).

Lacreuse & Fragaszy (1997) state that the relations among hand preference, hand performance, and hemispheric lateralization are not yet understood. Exploratory procedures are optimal for the detection of a specific property. In order to pick up information about the shape of an object, Lacreuse & Fragaszy (1997) had participants spontaneously execute a “Contour Following” movement, which is adapted to extract the
shape, but less adapted to perceive any other dimension of the stimulus. Second, recent investigations of the lateralization of human tactile strategies, measured by the location of hand contacts on shapes, have shown that the left hand explored a broader surface area of the shapes than the right hand (Lacreuse & Fragaszy, 1997). Exploratory procedures should provide considerable insight into the understanding of the relations among hand preference, hand performance, and hemispheric lateralization in non-human primates (Lacreuse & Fragaszy, 1997). The participants for this study were four adults (two males and two females) who were self-confessed right-handers for writing, drawing, throwing a ball, brushing teeth, hammering, and using a racquet. None of their close relatives was left-handed. Additionally, a total of 21 capuchins, comprising 12 adults, 6 juveniles, and 3 infants, participated in the experiment.

The questions that were specifically addressed were, “are asymmetries present in the way information is gathered by the left and right hands?” “Is there any advantage of one hand compared to the other?” “What are the relations between exploratory procedures and the efficiency of tactile explorations?” “Are there any differences in strategies and/or performance among left-handed, right-handed, and ambidextrous participants?” Finally, because this group of capuchins preferred the left hand for performing this task, what advantage, if any, does this preference confer?
Figure 4. The Haptic Exploratory Procedures performed by Humans and Monkeys. Grasp and Pull exploratory procedures were only performed by Capuchins (Lacreuse & Fragaszy, 1997).

The stimuli objects were two sets of 12 clay objects, each set scaled to fit the hand size of one species (see Figure 5). The objects were designed to elicit different types of manual exploratory procedures for seed retrieval. They had different shapes designed
to elicit contour movements, lateral movements, probe explorations, and a variety of movements combining the previous ones.

Figure 5. The Box Apparatus used with the Capuchins and the 12 Clay Objects used with Both Species (Lacreuse & Fragaszy, 1997)

Hand movements for both humans and capuchins were scored from the videotapes, in slow motion. A time code (hours, minutes, seconds, and tenths of a second) was marked on each tape and the identity of each monkey was audio recorded. The analysis was restricted to a maximum of 10 movements per participant and per shape.

Humans scanned the shapes in an exhaustive manner, in order to collect all the seeds from the stimuli, whereas capuchins limited their explorations to a very small portion of the shapes, usually the area surrounding the initial hand contact (Lacreuse & Fragaszy, 1997). The authors hypothesized that in both species the left hand would
outperform the right hand. The results did not confirm this; the percentage of successful exploratory procedures was the same for left and right-handers in humans. In humans, the left hand is usually found to be better than the right for tactile perception. Findings of no hand asymmetry were also reported in the literature. Lacreuse & Fragaszy proposed that it has been confirmed in a series of experiments with humans showing that the left hand/right hemisphere explored larger areas of stimuli than the right hand/left hemisphere. The dissociation between a left-hand preference and no hand advantage in performance does not support the idea that using a particular hand conferred an adaptive advantage to perform the tactile task (Lacreuse & Fragaszy, 1997). The monkeys acted naturally while the humans tried to get the most seeds in the least amount of time. Very few studies have confirmed the opposite view. Horster and Etlinger (1985), as cited in Lacreuse & Fragaszy (1997), reported in macaques that left-handers tested with their left hand performed better than right-handers tested with their right hand in a tactile task.

Steenhuis & Bryden (1999) also studied the relation between hand preference and hand performance. A total of 52 right-handers and 48 left-handers were tested for manual proficiency and preferences using a range of tasks. Self-professed right and left-handers showed greater preference for, and superior performance with, the preferred hand. Left-handers use their non-preferred hand more often and in some instances are more skilled with it than right-handers (Steenhuis & Bryden, 1999). The overall data indicated that a complete description of handedness would only be provided by careful consideration of the nature of the preference and performance measures one uses (Steenhuis & Bryden, 1999). Steenhuis & Bryden point out that measuring handedness is not straightforward.
In the Neuropsychological literature, handedness measures have included self-report, preference questionnaires, observation of preference, and performance differences between the hands. They also point out that it is a challenge when establishing correlation between these various measures. The authors compare the various shapes that these questionnaires create when the data is analyzed. The J-shape, bimodal curves, and normal distribution curves ranging in skeweness have been accounted for in several studies, depending on the quantity of questions included in the questionnaire. Steenhuis & Bryden note that it is not simply a matter of changing the characteristics of the hand preference distribution by asking more questions about handedness. Since several dimensions appear to be present when referring to hand preference, they have characterized in their studies two different types of activities. One of the characteristics is represented as “skilled,” such as writing and throwing a dart, and “less skilled” activities, involving picking up objects, and petting a dog or a cat. They reported that 80% of right and left-handers reported a strong preference for one particular hand for skilled activities. In contrast to skilled activities, only about 25% of participants reported strong preferences for one hand for the less skilled activities. The distribution of preference scores on the “skill” factor was J-shaped, whereas the distribution on the “less skilled” factor was right-biased normal (Steenhuis & Bryden, 1999).

Low correlation has been reported between different measures of manual performance, and their analyses support several dimensions of hand performance (Steenhuis & Bryden, 1999). Some left-handers have strong preferences for the left hand for certain activities and strong preferences for the right for others (Steenhuis & Bryden,
This “inconsistent” left-handed group shows a very clear dissociation in preference and performance for activities that require fine manual dexterity and speed, and activities that involve whole arm movements and strength (Steenhuis & Bryden, 1999). The left hand was better for the former and the right for the latter (Steenhuis & Bryden, 1999). This experiment examined the relation between multidimensional hand preference, including behavioral preference, observed hand use, and hand proficiency on a range of manual tasks. The questionnaire that was administered was the Waterloo Handedness Questionnaire. For the performance tasks Annett’s pegboard task and the Tapley-Bryden dot-filling task were included. The results for the performance showed that the preferred hand of both self-professed left and right-handers had more skill, strength, and use than the non-preferred hand (Steenhuis & Bryden, 1999).

They compared the questionnaire results to the actual data collection of the tasks and many of the groups that reported being left-handed presented preferences of both hands on several tasks. This group was later named “mixed-handedness.” They showed in several task’s performance the use of either the right or left hand as the most predominant. The use of the questionnaire in this study has shown the value of comparing between subjective responses and actual objective observations that allow the experimenter to carefully identify the strictly left-hander of a right- or mixed-hander, the strictly right-hander from the left and mixed-hander, and the mixed-hander from the strictly left or right-hander. The left-handed individual is left-handed for tasks involving fine manipulation (like writing, finger tapping, and Purdue Pegboard performance), but
right-handed for tasks involving arm movements and strength (grip strength and throwing accuracy).

Bryden and his colleagues found that left-handers move much further to the right whereas right-handers moved further to the left. Right- and left-handers moved further when they began the task with the preferred hand than when they began with the non-preferred hand (for example, rightward with the left hand). The data presented in this study strongly support the contention of Steenhuis (1996), as cited in Steenhuis & Bryden (1999), that the skill level of a task, independent of whether one is considered a left- or right-hander, is an important factor in determining whether strong preferences and skill differences emerge, although further research is needed to test this hypothesis directly.

Hand preference is a characteristic that develops throughout life, although it is mainly established during the first years of life (Galobardes, Benstein & Morabia, 1999). Societal pressure directly results in switching hand preference among innately left-handed people and may also decrease the overall prevalence or reported innate left-handedness (Galobardes, Benstein & Morabia, 1999). Left-handers are less certain about their hand preference than are right-handers. Some left-handed people may have switched so early to right-hand habits through parental and societal pressure that they do not recall their innate handedness (Galobardes, Benstein & Morabia, 1999). At the same time, the results cannot rule out the possibility that higher mortality among left-handed participants explains the decline of innate left-handedness with age (Galobardes, Benstein & Morabia, 1999).
Around one in ten people are left-handed (Aldersey-Williams, 1999). Much of the effort to recognize the needs of this large minority focuses on teaching children to write from left to right without difficulty (Aldersey-Williams, 1999). In order not to cover what they are writing, left-handers have a tendency to mirror-write or to grip their pens uncomfortably, which can become a serious handicap by the time they are taking exams (Aldersey-Williams, 1999).

But almost every unimanual activity, from zipping one’s trousers to using a cash machine, is biased in favor of right-handers (Aldersey-Williams, 1999). The discrimination designed into so many products may be more than an inconvenience (Aldersey-Williams, 1999). There are a few products where left-handers may accidentally be the gainers. Singer sewing machines, whether in error or by design, gave the skilled job of steering the cloth past the needle to the left hand while the right cranks the wheel (Aldersey-Williams, 1999). Computer keyboards with the numeric panel on the right, and the computer mouse, produce problems as well (Aldersey-Williams, 1999). Logitech is one computer accessory manufacturer that has introduced a left-handed mouse, designed by the Californian firm Frogdesign (Aldersey-Williams, 1999). Cameras and video cameras also pose a problem for left-handers with the buttons located on the left side and the handle on the right (Aldersey-Williams, 1999).

**Questionnaire Research Studies**

Researchers have studied ways in which handedness can be identified and studied with the completion of certain tasks given by the experimenter Annett’s (1995).
handedness questionnaire, as cited in Peters (1998), was used to identify their preferred and non-preferred hand. Peters (1998) explains how empirical evidence can be provided in handedness questionnaires, for example:

a) comprise items that cover skilled and unskilled activities

b) be sufficiently long to capture a "mass effect" of variability in lateral preferences over a range of items

c) allow graded answer options for individual items rather than forced left/right choices. When using questionnaires that meet these criteria, it is possible to establish significant correlation between hand preference and performance even within a group of right-handers

In addition, such questionnaires are flexible enough to accommodate a great variety of handedness classification schemes As Peters (1998) suggests:

"The first criterion that should be taken into consideration for the evaluation of a hand preference questionnaire is whether or not it has face validity That is, such questionnaire should reflect a common understanding of handedness in terms of preferences of everyday activities, and stand in a meaningful relation to the self-classification of individuals A second criterion is construct validity A questionnaire should relate to some underlying theoretical concept of handedness For instance, in the testing of generic models, the genotype thought to underlie handedness forms should be captured in some way by the phenotypic classification, which, in turn, is based on a handedness questionnaire Finally, there is the need for external validation Here, particular emphasis should be placed on the relation between preference and performance After all, if preferences are not reflected in performance one can question the usefulness of the preference measures (p 77-78)"

The assumption is that longer questionnaires will cover a greater range of activities and will therefore afford a more differentiated picture of an individual's hand preferences (Peters, 1998) On the other hand, shorter questionnaires may be considered those with 10 items or less. These have been used quite effectively for specific applications When
attempting to find which hand preference items best label handedness in children, Peters (1998), found that "writing" and "drawing" were the most useful items.

In addition to the length of the questionnaire, the mode of answering must also be considered. First, there is the forced choice, where participants simply answer "left" or "right." Researchers such as Annett (1995), as cited in Peters (1998), have provided an additional choice questionnaire mode, which permit an "either" response. Oldfield (1971), as explained in Peters (1998), is composed of 5-choices including the "either hand" option that is absent in Annett's questionnaire modes. The sensitivity of outcome to answering options was also shown by Williams (1991) who compared the 10-item Oldfield questionnaire (essentially a 5-choice answer option) with the forced 12-item Annett (1995) questionnaire, as cited in Peters (1998), and found that the Oldfield procedure resulted in more "either hand" choices which, with the Annett questionnaire, would more likely have been "left" choices.

Peters agrees that when choosing motor tests for the purpose of handedness determination, the degree to which a test distinguishes between preferred and non-preferred hand performance may be used as one selection criterion. The literature also explained that between-hands differences may be present when using tasks such as throwing and writing, which are usually performed with one hand. Tests that incorporate features or over-learned activities, such as the dot-filling test, can be expected to provide information that is not drastically different from information that would be obtained by noting the time taken to write a short sentence with the preferred and non-preferred hands.
One would expect these tests to be very sensitive to practice effects. It has been noted by Peters that no task is entirely free of transfer effects. Studies in which reading and consequent manipulation preferences have been empirically determined would therefore find different behavioral responses as a function of the size of the object reached for (Peters, 1998). Handedness preference might be affected when the object used is larger than the normal size. Hammering and brushing teeth will serve as examples for activities that show a strong correlation to overall hand preference, and opening a jar lid will serve as an example of an activity that shows a weaker relation to hand preference. Peters anticipated the importance of items that he calls “unskilled,” which are characterized as “weak” items in his study. When such weak items are added to the questionnaire, right- or left-handers who are less consistent in their hand preference choices will show smaller between-hand performance differences than those who show strong consistent left- or right-hand preference. This difference does not emerge when a shorter questionnaire is used. Peters suggested that a preference/performance relation becomes visible only when there is a range of choices for answering each item, which allows a participant to express the strength of preference for a given item.

Some of the recommendations for a questionnaire that can be used without fear of missing important information that might be of relevance in the context of research in psychiatry, cognitive neuroscience, and neuroanatomy are the following (Peters, 1998):

1. The questionnaire should provide a mix of primary items that relate to skilled activities and items that capture unskilled activities.
2. There should be a sufficient number of such items to produce a “mass effect,” which allows for finer inter-individual gradual and successive stages in hand preference scores.

3. Participants should be allowed to answer items with graded answer options to do justice to the fact that gradual and successive stages in strength of preference have meaningful performance correlates.

4. From a more practical point of view, the questionnaire should be of an appropriate length in order to allow direct comparison between other studies in the literature.

Calvert & Bishop (1998) also studied how to measure handedness (or hand preference), but in their case using continuous behavior. The question of how to measure handedness is fundamental for anyone wishing to explore the origins or correlates of lateralization (Calvert & Bishop, 1998). Although some authors advocate a dichotomous classification of handedness, most researchers prefer to treat handedness as a continuous extent. The most popular approach is to use a range of unimanual (or bimanual but asymmetric) actions (Calvert & Bishop, 1998). Handedness inventories have been shown to have good reliability, and good validity, since the preferred hand typically correlates well with the observed behavior (Calvert & Bishop, 1998). Nevertheless, they have their critics. As Boklage (1980), as cited in Calvert & Bishop (1998), remarked:
"(the) real worst fault seems to lie in the arbitrary equal weights assigned to the various
dichotomies. Writing takes its place alongside hammer and spoon as equally considered indicators
Although it is conceivable that this might not be wrong, I cannot be comfortable with its arbitrariness (p
117)"

One alternative approach to handedness assessment involves quantifying the relative skill of the two sides on a performance task such as peg moving or tapping (Calvert & Bishop, 1998). Different tests of relative hand skill are poorly intercorrelated, so one will get a very different result depending on whether the choice is to measure speed, dexterity, steadiness, or tactile sensitivity. There seems to be no absolute criterion to determine whether one questionnaire is any better than another, and/or which determines one factor or several (Roy, 1996). It has been suggested that one reason why some performance tasks give a bimodal distribution of scores for left and right-handers while others do not is because tasks vary in terms of the extent to which there will be "transfer of training" effects from practiced activities such as handwriting. On tasks that involve holding an implement such as dotting in squares, the distributions of right-minus-left hand scores for left- and right-handers are quite distinct, whereas on other tasks such as peg moving, there is substantial overlap. Finally, skill difference scores (for example, right-hand performance minus left-hand performance) typically have much poorer test-retest reliability than do preference scores from inventories, so even with well motivated and well-practiced people, there is likely to be quite large error of measurement (Calvert & Bishop, 1998). While all three studies discriminated left- from right-handers, only the
Quantification of Hand Preference task (QHP) used by Bishop et al. (1996), as cited in Calvert & Bishop (1998), was shown to distinguish subgroups of right-handers. Questionnaire-based studies of hand preference have indicated that hand preference for unskilled actions (such as picking up objects) are weaker than hand preference for performing skilled activities (Calvert & Bishop, 1998). The aim of this study was to replicate and extend the original study by Bishop et al. (1996), as cited in Calvert & Bishop (1998), by comparing three different tasks that were selected to differ in terms of skill, to see whether the task used made a systematic difference in the degree of preference that was observed in the QHP paradigm. A second aim of the study was to see whether the QHP approach was able to differentiate subgroups within the left-handed population as well as subgroups of right-handers (Calvert & Bishop, 1998). A third question that was considered was whether left-handers behave like mirror-image right-handers (Calvert & Bishop, 1998).

It has been suggested that left-handers tend to be less lateralized overall than right-handers (Annett, 1981 as cited in Calvert & Bishop, 1998). To some extent, this could be due to the pressures of living in a right-handed world. However, a deeper, neurobiological explanation has been proposed by theories of the origins of handedness, which maintain that there are genes biasing to the left. On this view, the observed distribution of hand preference reflects an underlying mixture of genotypes, some of which are biased to right-hand preference, and some which are unbiased to either side (Annett, 1978 as cited in Calvert & Bishop, 1998). Whereas the majority of right-handers will be people with a biologically determined bias favoring the right hand, left-handers will be a mixture of
individuals with no such bias, or with a rightward bias that is counteracted by chance environmental influences that favor the left side (Calvert & Bishop, 1998). If this is the case, it may be expected to see less strong preferences on the QHP for left-handers than for right-handers. They used Annett’s Handedness Questionnaire (1995), which asks about direction of hand preference without including quantifiers such as “usually” and “always.” Respondents are asked to report whether their preference is for left, right, or either hand for a range of 12 activities: throwing, writing, holding a racquet, striking a match, cutting with scissors, threading a needle, using a broom, shoveling, dealing cards, hammering, using a toothbrush, and unscrewing the lid of a jar.

In the light of previous self-report studies of hand preference, it was anticipated that use of the preferred hand would be stronger for skilled than unskilled tasks (Calvert & Bishop, 1998). They also noticed that all participants tended to use the preferred hand when reaching in ipsilateral space, with the use of the non-preferred hand being observed for actions in contralateral space, but the tendency to use the preferred hand overall was less pronounced for the pointing task than for the card-reaching or placing tasks. This suggests that interaction with the environment in extrapersonal space maybe a key factor contributing to manual dominance and that the lateralization of motor skill interacts with this attentional bias. In the differentiation of preference subgroups, the sample size was small, and so power to detect a significant difference was not high.

The data presented here provides further evidence that hand preference can be quantified by observation, using direct measurement of the extent to which hand preference will be maintained when carrying out actions in different spatial locations.
relative to the body midline. The QHP task and Annett's Questionnaire have shown to be sensitive to the degree of hand preference, within as well as between handedness groups. Preferences such as writing and throwing suggest these are well-lateralized skills but the tasks mostly requiring strength are not (Provins, Milner & Kerr, 1982). In a replication factor analysis, the use of scissors gave a factor loading of 0.62, drawing gave a factor loading of 0.88, and dialing gave a factor loading of 0.65 (Liederman & Healey, 1986).

Deutsch & Springer (1989) suggest a widely used questionnaire to measure hand preference. Oldfield developed this questionnaire at Edinburgh University. Participants are asked to indicate their preferred hand for writing, drawing, throwing, cutting with scissors, brushing teeth, cutting with a knife without a fork, using a spoon, holding a broom (upper hand), holding a match while striking, and holding a lid while removing it from a box. The questionnaire yields a laterality quotient that ranges from -100 for extreme left-handedness, through zero for equal use of the two hands, to +100 for extreme right-handedness.

In a study of over 1,000 undergraduates at the University of Edinburgh who completed the questionnaire, most showed a consistent preference for one hand, few showed no preference. Those showing right preference, however, tended to show their preferences more strongly than those showing left preference. Findings like these have led some investigators to speak of right-handers and non-right-handers, rather than right-handers and left-handers (Deutsch & Springer, 1989). They also state that the way in which participants are classified into different handedness groups is critical for the outcome of research investigating handedness as a variable. Most studies using
questionnaires attempt to classify their participants in terms of handedness based on their scores (Deutsch & Springer, 1989). Problems arise, however, because handedness is not a simple all-or-none dimension; a decision, most likely arbitrary, must be made about the placement of the boundaries between handedness group categories (Deutsch & Springer, 1989). In an attempt to avoid this problem, Deutsch & Springer (1989) clarifies that other studies do not form groups based on test scores, but rather use the actual scores in the handedness measure. For either of these approaches, however, different types of questionnaires may yield different classifications for a group of participants. In light of this, it should not be surprising that experiments investigating the effects of handedness sometimes yield conflicting results. Differences in the way participants are classified may account for some or all of the conflict.

**Purpose of the Study**

Even though at least 1 in 10 people in the United States is left-handed (US Public Health, 1962), very little attention has been given to the handedness of an operator when selected for the job (Salvendy & Seymour, 1973). Many industries provide their employees with a fault analysis and instruction schedules of the tasks they need to complete satisfactorily (Salvendy & Seymour, 1973). However, what if the operator holds the tool in a certain way that may cause an injury or possible loss of equipment due to this failure?

The purpose of personnel selection is to select the most appropriate person for a job (Salvendy & Seymour, 1973). The issue begins with the fact that nine out of ten
people are right-handed, which means that tools, implements, machines, work spaces, homes, and the general technical environment will also be right-handed (Coren, 1992).

In this research, tools designed for right-handers were provided and that are issues of complaint for left-handers. Most of these complaints have to do with tools, implements, machines, and architectural design. For example, in the industrial realm, we find that metal shears, leather shears, hedge shears, pruning scissors, tailor’s pinking scissors, and even barber’s hair cutting scissors are still available only in the right-handed design from the usual retail outlets. Electric scissors and the barber or hairdresser’s electric clippers are right-handed.

In the right-handed kitchen, can opener, soup ladle, coffee pots, cooking pans, beverage servers, gravy boats, water reservoir on the left, lid opens to the left, measuring cups, coffee mugs, knife blades, electric carving knives, electric food slicer, salad and pastry forks, pastry server, cheese server, ice cream scoop, single-blade potato peeler, microwave oven door opens from right to left, clothes dryer, and kitchen sinks.

In school supplies, left to right writing pattern is set up for a right-handed writer, simple spiral bound notebooks used by many students shows clear partiality for the right-hander. T-squares, drafting machines, technically scaled rulers, scarcity of desks with left-handed writing tablets, typewriter or computer, the keypad on the QWERTY design is placed on the right side of the keyboard so that it is easy and natural for the right-hander to use but requires the left-hander to cross his body or shift his position completely to use it, adding machines and desk calculators usually have their adding, subtraction, totaling, and other mathematical function keys on the right side, computer
printers (on/off switch, the pattern pressure lever, etc.), floppy disk drives are usually located on the right side of the computer chassis, and copy machines. These are some of the many examples of tools and appliances that are commonly designed for the right-hander.

In the right-handed workplace, in industrial settings such as factories, mills, machine shops, or any other place where heavy tools or equipment are used, we find an environment quite badly designed for the left-hander. For example, the drill press, saws (places the arm directly in line with the saw blade and seems to invite a bad cut), portable power tools, power saw, and safety switches (this switch is usually in position where it can be easily be depressed by the right thumb). These tools are often difficult, unwieldy, awkward, and fatiguing for a left-hander to use. On-off switches and safety switches seem to be set up for the convenience of the right-hander. Assembly lines make the presumption that everyone is right-handed in the placement of parts, the direction that the belt moves, and the position of the workers (a left-handed might cause an accident when using the opposite hand as opposed to the others). Heavy earth-moving equipment, such as cranes, scrapers, and spreaders, usually place the most important and frequently used controls at the right side, for comfortable use by the right-hander. For instance, the lever that raises, lowers, and alters the angle of the blade of a bulldozer is found placed conveniently for the right-hander on the right side. More examples, surgical instruments, common dentistry station, chemical and pharmaceutical equipment, chemical beaker, standard microscope, controls of most X-ray and other high-tech diagnostic units.
Ergonomics or human engineering is the scientific discipline that focuses on the study of human movements and behavior patterns with the goal of best designing jobs and machines to fit the worker. One fact that has clearly emerged from ergonomic studies has to do with the way in which hands habitually turn. For the right hand, the most powerful, most natural, and best-controlled movements involve clockwise rotation, while for the left hand, counterclockwise rotation is best. Screws are invariably threaded so that a clockwise motion is associated with driving the screw forward. The left-hander’s natural turning tendency is counterclockwise, which means that the left-hander will suffer from a reduction in strength and control when using a screwdriver to advance a screw for insertion. And, just to confirm the lack of left-handed tools, more examples of right-handed equipment include the common camera, motion pictures and video cameras, rifles, fishing rods, eggbeaters, team sports (such as field hockey and polo), record player, TV’s, stereo tuners, compact disk players, tape recorders, books, and the standard military turn are also oriented toward the right-hander.

There are reasons to believe that the right-handed design of the world may actually constitute a danger for the left-hander. The left-handed worker is forced to use this tool despite its right-handed design if he wants to work in an industry that utilizes this kind of machine. There are two ways in which the left-hander might accommodate to these design problems. The first is to give in to the pressure of the right-handed world and begin to manipulate the work with the right hand. The other way is to insist on using his left hand. Both of these ways increase the probability of accidents. Some examples of accidents reported by left-handers are (Coren, 1992)
• Accidents of any sort when at work or in the workplace
• Accidents while engaged in any activity at home
• Accidents while participating in a sports activity
• Accidents while using any kind of tool or implement
• Accidents while driving a vehicle

Further, if we look at the chance that a left-hander will have an accident in more than one category of activity, we find that they are 78% more likely to have such a double mishap (Coren, 1992). They are 20% more likely to have an accidental injury when engaged in sports, 25% more likely to have such an injury when at work, 49% more likely to have an accidental injury when at home, and 51% more likely to have accident-related injury when using a tool, machine, or other implement (Coren, 1992). One of the greatest surprises was revealed in the area of driving. Left-handers seem to have more trouble in traffic than do right-handers. Overall, left-handers were 85% more likely to have an accident-related injury when driving a vehicle than were right-handers (Coren, 1992).

The focus of this study involved the completion time between right-handed participant’s preferred hand and tools, and the difficulty that they encompass in order to complete the task when using a tool that has not been used previously during the learning process. These tasks are used everyday in school, arts, artisan’s work, engineering work, house chores, and many other technical and non-technical jobs. The amount of time to complete a specific task (for example, cutting wool) determines the total time to complete
the job (making clothes and many other items) Considering the amount of people that are left-handed, there is a need to consider tools that are intended for left-handers. For this reason, the experimenter provided right- and left-handed tools to their preferred hand when measuring completion time. Handedness can be attributed to birth and forced learning behavior.

This research investigated the performance of right-handers using their preferred hand in representative tasks that are commonly performed in manual work. Research has shown that much industrial work involves reaches and moves that are performed either ballistically or under visual control (Hoffman, 1997). The conclusions of these experiments are related to industrial performance of left- and right-handed persons.

Statement of the Problem

Selection of operators for industrial, mail distribution, and domestic tasks, as well as many other tasks, may be dependent on the handedness of the individual, particularly when machines are designed for a specific hand. Left-handed individuals have not been regularly considered in the ergonomic design of products and places to work. Approximately 10% of the population is left-handed. There is a great need to collect ergonomic data for left-handers. The performance of task completion time between left- and right-handers changes when using their preferred hand in combination with “improper” and “proper” tools. The focus of this research involved the measurement of completion time on the participant’s preferred hand and ergonomically designed tools. The difficulty that they encompass in order to complete the task when using a similar...
tool with a different ergonomic design was also observed. The importance of such data is also demonstrated by the fact that the percentage of left-handers in the population will continue to increase in the future.

Statement of Hypotheses and Predictions

Based on the effects and possible dangers of completion time when using the preferred hand with an "improper" tool in the workplace, the following predictions and hypotheses were postulated.

Experiment 1. Scissors cutting around a circular path using the right hand with a "proper" and "improper" tool

H: Completion time will be faster when cutting around a circular path with a "proper" tool.

Prediction: Scissor cutting is a strongly laterализed task (skilled task) that will provide a strong advantage when using the preferred hand. The preferred hand will perform a task faster when using a "proper" tool.

Experiment 2. Using a computer mouse to dial numbers using the right hand with a "proper" and "improper" tool

H: Completion time will be faster in a mouse manipulation task on a computer using the "proper" tool.

Prediction: Mouse manipulation task on a computer is a strongly laterализed task (skilled task) that will provide a strong advantage when using the preferred hand. The preferred hand will perform a task faster when using a "proper" tool.
CHAPTER II

METHODOLOGY

Experimental Design

The present study identifies the dominant hand with the use of Annett’s (1995) 12-item Handedness Questionnaire. A comparison of the questionnaire handedness preference, and the skilled activities was provided in order to show the reliability of preference and performance. Skilled activities are defined as requiring the hand preference for the use of tools and manipulation of objects strongly lateralized in self-professed right- and left-handers (Steenhuis & Bryden, 1989).

“A Proper tool” is the ergonomically designed tool for a specific hand to use in order to complete a task. An “Improper” tool is the ergonomically designed tool that is used with a specific hand other than the one it was designed for in order to complete the same task. For example, left-handers may consider a “proper” tool, the left-handed tool, and as the “improper” tool, the right-handed tool. The tasks were completed using one hand, the preferred hand. Normal people mostly practice these two tasks, either on their jobs or at home. The use of practiced tasks increases the sensitivity of hand preference in the questionnaire and in the tests. The questionnaire provided questions about skilled items, which showed hand preference and a strong correlation with hand performance. The writing hand and drawing hand are the crucial items when confirming hand preference (Williams, 1986). Many of the school chairs are designed for right-handed students. The arm rest is located in the right and an entry space for the body to accommodate at the left. It is very difficult for left-handers to write or perform tasks while sitting in these “ergonomically” designed chairs for right-handers.
The first study involved the use of right and left-handed scissors with their right hand. A circular path (Drury tracking task) was presented to the individual to cut (See Appendix C) The participant cut with their preferred hand utilizing a right- and left-handed scissors. The performance was measured in task completion time during both hand tryouts with a stopwatch.

The second study involved a Mouse Manipulation Task using a left- and right-handed mouse. A set of problems were given to the participant. The participant solved the problems as they appear on the paper using the mouse. Only one repetition for each test, and the same format was used for each participant. The proper and improper mouse was located on the right side while using their preferred hand. Completion time was also measured with a stopwatch. Peters & Durding (1978, 1979), as cited in Roy (1996), have shown that the rate with which one can tap a key with the index finger is a reliable test, and that it correlated with hand preference measures.

Conclusions were made from the comparison between the tasks completion-time. Difficulty can sometimes be seen when accomplishing a task with one hand and an improper tool. This difficulty creates a time lapse between the task completion time with the preferred hand and the design of the tools used. During learning, participants must take breaks allowing rest from a leftist thinking and also an opportunity for more relaxed, more rightist thinking, for example, gazing, relaxing, doodling, or listening to music (Brown, 1979). Training was not offered in this study since these tasks have been previously practiced throughout an individual’s lifetime. Does the completion time of specific tasks differ across left- and right-handed people? This experiment hypothesis states that the task completion time between the preferred hand and the designed tools
used differ. These reviewed studies have shown that the reaction time between preferred and non-preferred hands differs slightly. When using the non-preferred hand and the “improper” tool, the time to complete a task will increase in comparison when using their preferred hand and “proper” tool.

**Instruments**

Two identical scissors, a left-handed and a right-handed, were utilized for the Scissor Cutting Task. Two identical mice, left-handed and right-handed mouse, were utilized for the Mouse Manipulation Task. For the identification of hand preference, Annett’s 12-item Handedness Questionnaire (1995) was utilized as the handedness inventory for each of the participants. Playing cards were also used to identify their hand preference while shuffling and dealing them. Tools that were utilized to gather the information and record the data were the following: a pen, pencil, notepad and stopwatch.

**Participants**

Participants were recruited from Embry-Riddle Aeronautical University (ERAU). Students, faculty, and staff members were eligible to participate. The age of the participants varied from 17-60 years old (mean age=22). A total of 30 right-handed participants in good health, and no physical disability were used for this study. Right-handers (RH) were defined as those who wrote and threw with their right hand. The group of participants was strongly lateralized right- or left-handers as determined by Annett’s Handedness (1995) Questionnaire. After the participant signed ERAU’s Consent Form then Annett’s Questionnaire was administered and the right-handers were identified. The participants were randomly assigned to the experiment conditions.
Procedure

The experiment was a within-subjects design using their preferred hand with a “proper” or “improper” tool. A protocol document was prepared in order to give the same information to each of the 30 participants and to keep track of the introduction and test time (See Appendix A). Annett’s handedness questionnaire was provided before the tests. The tests were performed in random order, the use of right and left-handed scissors to cut between the circular path drawn on the paper and mouse manipulation task on a computer that were given on a paper using the right- and left-handed mouse. The order in which the tasks were given was randomized, which helped control for any potential carryover effects. Participants were informed that their performance was going to be observed and recorded. The main instructions were to concentrate on the task and to work at a maximum speed.

The same experimenter individually tested and scored each participant. Each participant was seated in an upright position and their chair adjusted so that their elbows were 50-100 mm above the working surface of the table (Hoffman & Halliday, 1997). The tools were placed in the same location on the table for all tasks (See Appendix E, Figures 8 & 9). Participants did not have practice trials, they received a demonstration on how to perform each test. The tests were taken once per participant. Errors were measured, but not considered as a dependent variable (when the participant clicked on the “backspace” and/or “clear” buttons in order to re-enter the data or clear input). No rest periods were provided during the task activity, but a one-minute rest was provided after the completion of both trials.
**Determination of Handedness**

*Annett's (1995) 12-item Handedness Questionnaire* was filled out by all participants before the start of the experiment. A 3 point scale was used to avoid confusion from the participants between the hand preference choices, and to maintain the clarity of the options: 1 = left hand, 2 = either hand, 3 = right hand, for the determination of handedness. This questionnaire was given before the motor performances were tested. The strongly left-handed participants had an average of 12 and a strongly right-handed an average of 36. Each participant’s average in the test determined if he/she was right-handed, and could participate in the experiment. If the participant had an average less than 24, then this participant was considered left-handed and was eliminated from the participant pool. If the participant had an average greater than 24, then this participant was considered right-handed and was randomly assigned to one of the right-handed groups.

**Performance Tasks’ Tests**

*Task 1 - Scissors Cutting around a Circular Path (Modified Drury tracking task)*

Participants used matched left- and right-handed scissors to cut between the marked track (See Appendix C). The diameter of the circle was 50 mm and the track width was 5 mm. Identical cutting conditions were used for all participants. Cutting time was measured using a stopwatch. Each participant performed the task once and the errors were not recorded.
Task 2 – Mouse Manipulation Task on a computer using a right- and left-handed mouse

Participants used a matched left- and right-handed mouse to solve a set of mathematical problems (See Appendix D). Similar conditions were used for all participants. The Mouse Manipulation Task was measured using a stopwatch. Each participant was offered the opportunity to perform the task one time.

Errors were measured, but not considered as a dependent variable (when the participant clicked on the “backspace” and/or “clear” buttons in order to re-enter the data or clear input). Errors were recorded in writing for comparison after the tests with all participants.

Two different experiments were performed using their preferred hand and tools (“proper” and “improper” tool), alternating each at each task. In order to allow comparison between the tasks, the performances were expressed in terms of seconds to accomplish each task.


The list of items that were included in the questionnaire were writing, brushing teeth, throwing ball, holding a tennis racquet, hammering a nail, using scissors, striking a match, threading a needle, sweeping with broom, shoveling with a large shovel, dealing cards, and unscrewing a jar lid.
Experiment Variables

Dependant Variables

Experiment 1  Scissors cutting around a circular path using the preferred hand with a “proper” and “improper tool

Dependant Variable

Completion Time

This variable was defined as the time, in seconds, to complete the task of cutting with scissors around a circular path. This task was to be completed at a maximum speed. This variable was measured using a stopwatch. Errors were not recorded.

Experiment 2  Mouse Manipulation Task on a computer using the preferred hand with a “proper” and “improper tool

Dependant Variable

Completion Time

This variable was defined as the time, in seconds, to complete the Mouse Manipulation Task on a computer. This task was to be completed at a maximum speed. This variable was measured using a stopwatch.

Independent Variables

Within-Subjects

- Tools (“ Proper” and “Improper” tool) “Proper tool is the ergonomically designed tool for a specific hand to use in order to complete a task. An “Improper tool is the ergonomically designed tool that is used with a specific hand other than the one it was designed for in order to complete the same tasks.
The analysis consisted of a series of Repeated Measures ANOVAs. The within-subject design used the same participants for each treatment condition (“Proper” and “Improper” tool). That is, every person received each level of treatment. Using SPSS the total completion time for each task using the “proper” and “improper” tools was analyzed. An (alpha) $\alpha = 0.05$ with a confidence interval of 0.95.
CHAPTER III

RESULTS

The analysis of the data collected from this experiment was accomplished utilizing SPSS. A General Linear Model ANOVA was used to interpret the results from both experiments. A significance level of $p = 0.05$ was utilized on both tests.

**Scissors Task Using Proper and Improper Tools**

The hypothesis stated that completion time is faster when cutting around a circular path with a "proper" tool. This hypothesis was supported. The prediction stated that the scissors cutting task would be a strongly lateralized (skilled task) that would provide a strong advantage when using the preferred hand. The preferred hand was likely to perform a task faster when using a "proper" tool. This portion of the hypothesis was also supported.

The mean time of the first group of 15 participants to complete the cutting task with the right-handed scissors was 32.57 seconds. The mean time to complete the cutting task with the left-handed scissors was 59.98 seconds.

An ANOVA was performed on this data and a significant main effect of completion time was obtained on the scissors task, $F(1,14)=29.05, p < 0.001$. AnEta Squared of $0.675$, which means that 67.5% of the observed effect is attributed to the independent variable tools. Table 1 shows the summary of the analysis when cutting with
both scissors. Figure 6 shows a graphical representation of the difference between the means on completion time for the scissors task. Right-handers performed faster when using a right-handed tool.

<table>
<thead>
<tr>
<th>Tool</th>
<th>SS(Tool)/SS(Error)</th>
<th>df</th>
<th>F</th>
<th>p</th>
<th>Eta Sq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scissors</td>
<td>5635.34 / 2715.90</td>
<td>(1,14)</td>
<td>29.05</td>
<td>&lt;.001</td>
<td>.675</td>
</tr>
</tbody>
</table>

Table 1: Summary Table of the Cutting Task with Right- and Left-handed Scissors
GLM ANOVA Within-Subjects Measures.

![Figure 6: Completion Time Bar Graph of Cutting Task With “Proper” and “Improper” Scissors.](image-url)
**Mouse Manipulation Task with Right and Left-handed Mouse**

The hypothesis stated that completion time would be faster on the mouse manipulation task using a computer with the “proper” tool. This hypothesis was supported. The prediction stated that the mouse manipulation task on a computer would be a strongly lateraled task (skilled task) that would provide a strong advantage when using the preferred hand. The preferred hand would be likely to perform the task faster when using a “proper” tool. This portion of the hypothesis was also supported.

The mean time for the second group of 15 participants to complete the Mouse Manipulation Task with the right-handed mouse was 3.1854 seconds. The mean time to complete the Mouse Manipulation Task with the left-handed mouse was 3.6137 seconds.

An ANOVA was performed on this data, and a significant main effect of completion time was obtained on the mouse manipulation task, $F(1,14)=11.47, p = .01$. An Eta Squared of 0.450, which means that 45.0% of the observed effect is attributed to the independent variable tools. Table 2 shows the summary of the Mouse Manipulation Task with both mice. Figure 7 shows the difference on completion time for the Mouse Manipulation Task. Right-handers performed faster when using a right-handed mouse than when using a left-handed mouse.
Table 2: Summary Table of the Mouse Manipulation Task with the Right- and Left-handed Mouse. GLM ANOVA Within-Subjects Measures.

<table>
<thead>
<tr>
<th>Tool</th>
<th>SS(Tool)/SS(Error)</th>
<th>df</th>
<th>F</th>
<th>p</th>
<th>Eta Sq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouse</td>
<td>1.37/ 1.68</td>
<td>(1,14)</td>
<td>11.47</td>
<td>.01</td>
<td>.450</td>
</tr>
</tbody>
</table>

Figure 7: Completion Time Bar Graph Mouse Manipulation Task With “Proper” and “Improper” Mouse.
CHAPTER IV

DISCUSSION

The results from the data obtained provided evidence of significance on both experiments. Completion time was faster when cutting around a circular path with a "proper" tool. Completion time was faster in the Mouse Manipulation Task on a computer with a "proper" tool. This means that when a participant utilizes the "proper" tool designed for their preferred hand on a task, the completion time will be faster than when given an "improper" tool.

Of primary concern for this study was the completion-time of two simple tasks, Scissors Cutting Task and the Mouse Manipulation Task. Most of the research done on handedness has been centered on handedness identification. The objective of this study was to examine the peoples' performance when forced to use improperly designed tools.

Right-handed participants volunteered and were treated in an identical manner. Due to the experience and knowledge on use of right-handed tools, right-handers showed better performance when using the "proper" tool (right-handed tool). Since these participants were not subjected to "improper" tools before, the effect of "improper" tools was clearly evident when measuring completion time. The participants were impressed with the results of their performance when completing the task with the left-handed tool. Some comments that were exchanged by them were “I had never thought of left-handed tools”, “The left-handed scissors was tricky, I couldn’t see what I was cutting”, “The
buttons on the mouse were confusing. I had to think about what I was doing and concentrate hard.

These comments raise the question, "How hard can it be for the left-handed individual to feel comfortable when using right-handed tools?" This study demonstrated not only the effects on right-handed participants when using "improper" tools, but it also brings to light, the difficulty and discomfort of left-handed people when faced with tools not designed for their preferred hand. If left-handers are confronted with tools and workstations that are disadvantageous to them, negative effects on work performance, worker satisfaction, and work safety may be experienced.

The significant main effect of completion time on both tasks clearly demonstrates the lack of engineering and design of everyday tools for the left-handers. One out of 10 people is left-handed, this means that 9 people are responsible for the engineering and considerations of the entire population.

Handedness preference is also considered in the aviation/aerospace application. What would the potential consequences be if a left-handed astronaut was responsible for an emergency situation and the ergonomics of the work area and tools were designed for a right-handed individual? What would the consequences be if time was critical for a success or failure? In the right-handed workplace, industrial settings such as, factories, mills, machine shops, or any other place where heavy tools or equipment are used, the environment does not consider the left-handers needs with "proper" tools. These tools that are commonly provided, right-handed tools, are often difficult, unwieldy, awkward, and fatiguing for a left-hander to use. Left-handers, or 10% of the population are forced to work with "improper" tools that may be detrimental to their performance.
CHAPTER V

CONCLUSION

The output of this research should be of consideration on every day tasks, proper selection of personnel on tasks, tool designs, and comfort of both left and right-handers. The results of these experiments indicate if there is justification for selection of personnel in certain tasks based on handedness and machine types. Leaders and personnel in charge of workers should be responsible for this decision and they should also provide the proper tools for use in order to achieve workers satisfaction, better productivity, and safety. Selection of personnel for industrial, manufacturing and other work areas should be dependent on the handedness preference of the individual, particularly when machines and tools are designed for a specific hand. As shown on these experiments, the person has a disadvantage in performing satisfactorily when tools can’t accommodate properly their preferred hand. A criterion for personnel selection should be taken into consideration where hand preference matches the handling procedures of the machinery provided by the company.
REFERENCES


APPENDICES
APPENDIX A

Thesis Study Protocol
Thesis Pilot Study Protocol
Administered by Lisnnette Nieves

I. Welcome the participant by the experimenter
   
II. Request the participant to:
   a. Sign ERAU’s Human Consent Form
   b. Deal cards (to the experimenter and himself)
   c. Request to sign his/her name on the participants’ signing sheet.

   Both of these tasks are going to be used to compare the answers given on the 
   questionnaire and present validity.

   Will answer any questions that the participant may have.

III. Have the participant fill out Annett’s Questionnaire in order to determine 
      handedness group.

      5 minutes or less will be used in order to compare the observed preference and the 
      results of the questionnaire.

      Will answer any questions that the participant may have.

IV. Brief the participant on the topic of the thesis without giving any details on 
    my hypotheses or specific details on the study in order to avoid confounds 
    from the experimenter to the participant

      Will answer any questions that the participant may have.

V. Randomly assign the participant the test

VI. Explain the test that the participant has been assigned to and what are the 
    measured variables

    Participants will be informed that their performance is going to be observed and 
    recorded in writing. The main instructions will be to concentrate on the task and to work 
    at a maximum speed. Using their RIGHT hand.

    a. Scissors

       i. Cut as fast as possible around the annular path using the proper 
          tool first (right scissors) and then the improper tool (left scissors) 
          with the preferred hand. Will explain how the timing will be 
          obtained.

       ii. Will answer any questions that the participant may have.

       iii. Provide the participant with the cutting test using the “proper” 
            scissors.

       iv. Log the time it took to complete it.

       v. Provide the participant with the cutting test using the “improper” 
          scissors.

       vi. Log the time it took to complete it.

       vii. Include test in the participant’s file for further evaluation by the PI.

    b. Mouse Manipulation Task using calculator from the computer

       i. Handout the paper with the problems that need to be solved.

       ii. Explain what needs to be done.

       iii. Solving problems as fast as possible with the proper tool first (right 
            mouse) and then with the improper tool (left mouse). Will explain 
            how the timing will be obtained.

       iv. Will answer any questions that the participant may have.
v. Provide the participant with the problem-solving test using the “proper” (right-handed) mouse.
vi. Provide the participant with the problem-solving test using the “improper” (left-handed) mouse.
vii. Compare both results from the proper and improper tool and the time that it took to complete the same task with both tools.

VII. Candy will be provided after the tasks are completed.

VIII. The participant will be debriefed by the PI on the hypotheses of the thesis and the importance of his/her data to the study. During this debrief the PI will answer any questions that the participant may have.

IX. The experimenter and PI will thank the participant for volunteering and for helping to obtain the necessary data for the completion of this thesis research.
APPENDIX B

Annett’s (1995) Handedness Questionnaire
Annett's (1995) Handedness Questionnaire:

Please indicate your preferences in the use of hands by putting the value in the preference column. Use 1 = left hand; 2 = either hand; 3 = right hand.

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

<table>
<thead>
<tr>
<th>List of items</th>
<th>Preference:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. write</td>
<td></td>
</tr>
<tr>
<td>2. brush teeth</td>
<td></td>
</tr>
<tr>
<td>3. throw ball</td>
<td></td>
</tr>
<tr>
<td>4. hold tennis racquet</td>
<td></td>
</tr>
<tr>
<td>5. hammer in a nail, hand that holds the hammer</td>
<td></td>
</tr>
<tr>
<td>6. use scissors</td>
<td></td>
</tr>
<tr>
<td>7. strike match, hand that strikes match</td>
<td></td>
</tr>
<tr>
<td>8. thread needle (which hand moves)</td>
<td></td>
</tr>
<tr>
<td>9. sweep with broom (lower hand when sweeping to the right)*</td>
<td></td>
</tr>
<tr>
<td>10. shovel with large shovel (hand that pushes the shovel)</td>
<td></td>
</tr>
<tr>
<td>11. which hand deals cards</td>
<td></td>
</tr>
<tr>
<td>12. which hand unscrews jar lid (small and light jar)*</td>
<td></td>
</tr>
</tbody>
</table>

**Do you suffer from any physical or other handicap that might influence your answers to these questions?** Yes____ No_____ Not sure_____

Total: ________
*Peters (1990) stated that the item of “opening a jar lid” is part of even the short list of a number of preference questionnaires and he finds it quite unsatisfactory in terms of consistency. Peters notes that the actual behavior of persons opening jars, in the case of a recalcitrant lid, persons changed readily from one hand to the other and back again. It also depends on the size of the jar to be held relative to the lid size. Similarly, when asked about holding a broom depends on how their body is oriented relative to the area to be swept. The lower hand holding the broom indicates the hand preference. For this reason, I have provided a better explanation of these tasks in order to obtain consistency between all items. **If yes, participants were eliminated from the study in order to avoid confounded data.
APPENDIX C

Test #1: Cutting Around Annular Path (1971 Drury Tracking Task)
TEST 1: Cutting Around Annular Path
APPENDIX D

Test #2: Adding Numbers Using Computer and Mouse
TEST 2: Mouse Manipulation Task

Part A

Please add/subtract the following numbers:

1. 23+47=
2. 389-203=
3. 1065+4398=
4. 290+4390=
5. 589+9487=
6. 1469+87=
7. 625+935=
8. 546-463=
9. 2936+14=
10. Please add all of your answers and write the total in the line provided__________.

Mouse Used (L for Left- or R for Right-handed Mouse):

Total Time ("Improper Mouse"): 
Part B

Please add/subtract the following numbers:

1. 1065+4398=
2. 589+9487=
3. 1469+87=
4. 23+47=
5. 389-203=
6. 625+935=
7. 290+4390=
8. 2936+14=
9. 546-463=
10. Please add all of your answers and write the total in the line provided ________.

Mouse Used (L for Left- or R for Right-handed):

Total Time ("Proper Mouse"):
APPENDIX E

Scissors Task Diagram & Mouse Manipulation Task Diagram
Figure 8: The Principal Investigator, Lisnnette Nieves Suarez, was seated next to the participant while explaining the procedures of the test and the measures of performance. While the participant completed the task, the Principal Investigator sat next to him/her in order to capture any interesting behavior.
Mouse Manipulation Task

Figure 9: The participant used first the right-handed mouse (on the left side of the drawing) to complete the task and then moved to the next computer (on the right side of the drawing) with a left-handed mouse to complete the second task. The Principal Investigator sat next to the participant in order to capture any interesting behavior.
APPENDIX F

Test #1 Data (12/5/2000) & Test #2 Data (11/30/2000)
Test #1 Data (12/5/00)
Scissors Cutting Task

<table>
<thead>
<tr>
<th>Participants</th>
<th>RCompletion Time</th>
<th>LCompletion Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>35.75</td>
<td>68.28</td>
</tr>
<tr>
<td>2</td>
<td>33.38</td>
<td>43.68</td>
</tr>
<tr>
<td>3</td>
<td>46.00</td>
<td>111.37</td>
</tr>
<tr>
<td>4</td>
<td>53.20</td>
<td>74.05</td>
</tr>
<tr>
<td>5</td>
<td>42.22</td>
<td>56.75</td>
</tr>
<tr>
<td>6</td>
<td>30.70</td>
<td>68.84</td>
</tr>
<tr>
<td>7</td>
<td>25.19</td>
<td>52.72</td>
</tr>
<tr>
<td>8</td>
<td>17.87</td>
<td>50.00</td>
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<tr>
<td>9</td>
<td>23.97</td>
<td>58.32</td>
</tr>
<tr>
<td>10</td>
<td>18.84</td>
<td>21.13</td>
</tr>
<tr>
<td>11</td>
<td>45.28</td>
<td>109.16</td>
</tr>
<tr>
<td>12</td>
<td>31.50</td>
<td>56.59</td>
</tr>
<tr>
<td>13</td>
<td>34.81</td>
<td>36.47</td>
</tr>
<tr>
<td>14</td>
<td>24.62</td>
<td>29.00</td>
</tr>
<tr>
<td>15</td>
<td>25.32</td>
<td>63.66</td>
</tr>
</tbody>
</table>

*Time recorded in seconds*
**Test #2 Data (11/30/00)**

**Computer Mouse**

<table>
<thead>
<tr>
<th>Participants</th>
<th>R Completion Time</th>
<th>L Completion Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.0288</td>
<td>3.0985</td>
</tr>
<tr>
<td>2</td>
<td>3.1906</td>
<td>3.4850</td>
</tr>
<tr>
<td>3</td>
<td>3.5956</td>
<td>5.1275</td>
</tr>
<tr>
<td>4</td>
<td>3.2863</td>
<td>3.3832</td>
</tr>
<tr>
<td>5</td>
<td>2.3201</td>
<td>3.0894</td>
</tr>
<tr>
<td>6</td>
<td>3.2575</td>
<td>3.4051</td>
</tr>
<tr>
<td>7</td>
<td>3.5068</td>
<td>3.4351</td>
</tr>
<tr>
<td>8</td>
<td>3.1097</td>
<td>3.2628</td>
</tr>
<tr>
<td>9</td>
<td>3.1215</td>
<td>3.1378</td>
</tr>
<tr>
<td>10</td>
<td>3.3756</td>
<td>3.0224</td>
</tr>
<tr>
<td>11</td>
<td>3.3328</td>
<td>4.0931</td>
</tr>
<tr>
<td>12</td>
<td>3.4375</td>
<td>4.1562</td>
</tr>
<tr>
<td>13</td>
<td>3.1128</td>
<td>4.0628</td>
</tr>
<tr>
<td>14</td>
<td>2.55380</td>
<td>3.2301</td>
</tr>
<tr>
<td>15</td>
<td>3.5512</td>
<td>4.2171</td>
</tr>
</tbody>
</table>

*Time recorded in minutes with seconds*