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Running head: ASYMMETRICAL INTERFERENCE BETWEEN HANDS.

Measuring Divided Attention With A Dual Task Paradigm:

Addressing the "Initial Value" Issue.

Ben Coleman, B.Sc.

A thesis submitted to the Faculty of Graduate Studies and Research

in partial fulfilment of the requirements for the degree of

Master of Arts

Department of Psychology

Carleton University

May 23, 1997

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Research acceptance of the thesis.

"Measuring Divided Attention with a Dual Task Paradigm:

Addressing the "Initial Value" issue".

Submitted by Benjamin Coleman, A.A.Sc, B.Sc,
in partial fulfillment of the requirement for the degree of Master of Arts.

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Abstract

Neuropsychological dual task research indicates that a greater right hand interference effect for right handed people will occur as predicted by the Functional Cerebral Space (FCS) model. Other research claims that this interference effect is due to an initial baseline right hand advantage, also known as the 'initial values' issue. The present study investigated the 'initial values' issue by different mechanical manipulations and statistical methods. Lateralized interference effects were examined in a sample of 71 subjects and a subgroup (N= 23) of this sample. Three different conditions were used to mechanically manipulate hand differences. The Standard condition produced a right hand advantage, the Adjusted condition eliminated any hand advantages and the Exaggerated condition produced a left hand advantage. Four different statistical methods were also used to control for initial hand differences. The altered Change score analysis method from the small sample produced the greatest right hand interference effect, which accounted for 70% of the variance. This altered statistical method and the Adjusted condition appeared to be the best methods for addressing the 'initial values' issue in a neuropsychological dual task experiment.

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Asymmetric Interference 1

Measuring Divided Attention With A Dual Task Model:

Addressing the "Initial Value" Issue.

The dual task model has become a widely used behavioural method to infer hemisphere lateralization of function (e.g., Kee & Cherry, 1990; Wolf & Cohen, 1980). The essence of the dual task procedure is that performance will decline when subjects carry out two tasks at once. The dual task method is easy to administer, is flexible, and allows for various speech and motor output and input tasks to be utilized for specific subject populations (Simon & Sussman, 1987). Dual task procedures are a useful research tool for testing different hypotheses about asymmetrical cerebral interference, lateralization of function, or more important to this study, for investigating theoretical models such as the prominent functional cerebral space (FCS) model proposed by Kinsbourne and Hicks (1978).

From a neuropsychological perspective, dual task performance reflects the possible degree and direction for which interference might exert its effects within the parameters of cerebral space. For example, an asymmetrical decrement in tapping performance of the hands produced by a concurrent cognitive task versus tapping alone indicate that the

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manual tapping task and the cognitive task are allegedly competing for resources from the same hemisphere (Kinsbourne & Hicks, 1978).

Manual performance for each hand is typically compared in conditions with and without a concurrent verbal task, such as recitation of a rhyme, anagram solutions, tongue twisters, or reading a passage (Kee, Bathurst, Hellige, 1983). When comparing the two conditions, right hand performance is usually disrupted to a greater extent than the left hand performance during concurrent verbal activity conditions. Consequently, if performance of a primary cognitive task interferes more with the right- than the left-handed tapping, it is likely that performance of the primary task is associated with greater left- than right-hemispheric neuronal activation. Therefore, lateralization interference effects are consequently highly dependent on inter-hand comparisons between dual task and manual task performances.

In their 1987 paper, Willis and Goodwin suggested that a major problem with neuropsychological dual task research consisted of using pretest and post-test raw scores to determine difference or "Change" scores. The inherent problems with these 'Change scores' was their insensitivity to actually detect lateralized interference effects (Willis and

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Goodwin, 1987). Also, overlooked by most neuropsychology researchers who used 'change scores', – originally introduced to neuropsychology research by Hiscock and Kinsbourne in 1978 – is that pre- and post-test measures are not always uncorrelated from the 'Change scores'.

Realizing that the pretest and post-test scores were highly correlated with these 'Change' scores, Willis and Goodwin (1987) re-analysed neuropsychological data involving dual task models (i.e., tapping while concurrently speaking) and used the recommended analysis of covariance procedure (e.g., Lord, 1967; Kenny, 1979, Linn & Slinde, 1977; Willis & Hynd, 1987). Their conclusions indicated that there were no differences to be found between inter-hand tapping rates, even after the "initial" (i.e., pretest) inter-hand differences were partialled out. In essence, they disagreed with the body of neuropsychological research which endorsed the dual task method of measuring vocal and concurrent motor movements (e.g., Sergent, Hellige, & Cherry, 1993; McFarland, Ashton, Rich, & Donald, 1989; Cherry & Kee, 1991; Bowers, Heilman, Satz, & Altman, 1978; Lomas, & Kimura, 1976; Wolf, & Cohen, 1980. See section on interference and dual task model that follows for more information).

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Purpose of paper. One purpose of this study is to demonstrate that traditional and altered methods for analysing differences between pre- and post-test scores in neuropsychological dual task models should produce significant, but different, results. Although the results may be different, it was argued that the altered statistical methods would account for more of the Change score variance than would the traditional analyses. Therefore, where neuropsychological dual task research is concerned, these corrected methods might be considered an advantage over the traditional ones.

The primary purpose of this study is to demonstrate that Willis and Goodwin's (1987) conclusions about the right-hand tapping decrement effects not reflecting left-hemisphere language were erroneous. Following a dual task procedure (e.g., Kosaka, Hiscock, Strauss, Wada, & Purves, 1993), with the initial inter-hand differences properly adjusted, as suggested by Kee and Cherry (1990), and utilizing appropriate statistical measures (e.g., Linn & Slinde, 1977; Lacascio & Cordray, 1983; Campbell & Boruch, 1975; Kenny, 1979), it is hoped that further evidence for asymmetrical interference of lateralized cerebral functions as predicted by Kinsbourne and Hicks (1978) FCS theory would be provided.

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Kinsbourne and Hick's (1978) FCS theory was initially extrapolated from prior cognitive constructs of attention (e.g., Kahneman, 1973a, 1973b; Broadbent, 1958; Allport, Antonis & Reynolds, 1972). Therefore, before explaining the intricacies of the FCS model, a brief review on interference effects and the dual task model applications to various attention theories is discussed in the section below.

Interference and Dual Task Model. The extent to which a task engages a person is called "workload". Workload is a construct that reflects the ratio of the level of performance called for by the task to the maximum limiting performance level of which the subject is capable. As workload increases, subjects begin to experience themselves focussing attention ever more intently on the task (Kinsbourne, 1981). The dual task method is one objective way for measuring 'workload' via performance levels of two concurrent tasks. The dual task model simply refers to the performance levels of a primary task and a concomitant secondary task. When two highly similar concurrent activities potentially interfere, speed and accuracy trade-offs come into play (Kinsbourne, 1981; Pashler, 1994a; Ballesteros, Manga, Coello, 1989). One scenario is that if both activities are maintained at their concurrent rate of processing,

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then accuracy decreases because of interference. Or else, accuracy may be protected by a reduction in the processing rate. Therefore, use of the dual task method becomes an ideal means for evaluating attention capacity theories via task interference.

The primary emphasis of attention theories (i.e., Single-channel, Allocatable, Multichannel, and FCS) is with the degree and direction of divided attention between tasks (e.g., Kinsbourne & Hicks, 1978; Allport, Antonis, & Reynold, 1972; Navon & Miller, 1987; Botkin, Schmaltz, Lamb, 1977). All of these theories, except for the FCS theory, fundamentally express that interference between tasks must occur within some type of 'mechanism' or 'channel' found within the brain. The FCS theory states that interference occurs by 'cross talk' between close neural centres being concurrently programmed and not by competition for a 'mechanism' or 'channel' in the brain.

Single-channel Theory. This model accommodates a 'mechanism' that resolves complex inputs and distributes them into separate channels. These inputs are then held in a rapid-decay sensory register and a filter selects its information sequentially by channel. After which the information is passed onto a long-term memory storage or covertly

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processed (Kinsbourne, 1981, Pashler, 1994a). Single-channel theory assumes that given a primary task, subjects would devote their full attention (i.e., capacity) to the task. There could not be any opportunity for attention to be shared between tasks because extra capacity does not exist.

Concurrent activity of two tasks would not be possible according to the strict sense of this theory. Signals from competing activity performance levels for a single mechanism create a "bottleneck" in the processing system (Pashler, 1994a; Kahneman, 1973b; Kinsbourne, 1981). It could be said that at any given stage along the channel's mechanism where the locus of the 'bottle neck' (i.e., interference) occurs, it occurs at the same stage across tasks (Kahneman, 1973b, Pashler, 1994a). Therefore, regardless of task difficulty, easy and difficult tasks are performed "at capacity" without overlapping one another (i.e., processed one at a time; Kinsbourne, 1981).

This model is analogous to a 'serial' processor (e.g., Broadbent, 1958) where attention is selected for a channel in an all-or-nothing fashion. Therefore, in a strict single-channel view, every day events, such as talking and walking, cannot occur simultaneously. You would

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have to stop to talk or walk and not talk. Of course, this is not the case. Most people can divide their attention between these two tasks and others.

Allocatable Capacity. In contrast to single-channel theory, allocatable capacity theory allows for a division of attention between channels that are concurrently occupied (Kahneman, 1973b). Hence, attention can be thought of as working in a parallel interdependent fashion.

This model also uses a 'mechanism' that resolves complex inputs and distributes them into the same channel. The inputs are then held in a rapid-decay sensory register while information is simultaneously encoded. After which the information is concurrently passed onto a long-term memory storage or actively implemented upon (Kinsbourne, 1981). Therefore, at whatever stage the locus of the 'bottle neck' is, it is not at the same stage across tasks. This is a distinguishing factor between the single channel and allocatable theories. Allocation of attention, in this fashion, predicts that dual task performances would go virtually unscathed, because the effect of a "bottleneck" would not impede upon the performance of the other task. This theory seems to be quite an

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advantage over the single-channel theory in that it would allow for the division of attention between tasks (Kahneman, 1973b).

A disadvantage to this theory is the ambiguity that arises when interpreting the results. For example, research has found that when two signals follow in rapid succession, the latency of response to the second signal is usually longer than it would have been had there been no preceding signal (Pashler, 1994a). Not only does the second processing sequence have to wait for completion of the first input, but the second processing sequence remains somewhat 'suspended' while feedback from the first input is monitored. These results would clearly support the single-channel theory. Yet, latency of the first response can also be increased (Pashler, 1994a; Kinsbourne, 1981), which in turn, provides support for allocatable capacity theory.

The Achilles heel for the allocatable model is the claim that attention provided to both concurrent activities would be performed 'at capacity'. That is, ongoing divided attention to both tasks remains consistent without jeopardizing any task performances. Researchers found that a subject's performance on at least one concurrent task was penalized by reducing attention previously allotted for the task's activity

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(Kinsbourne, 1978, 1982; Lempert, & Kinsbourne, 1985; Lomas, 1980; McFarland, & Ashton, 1975; McFarland, & Ashton, 1978; Pashler & O'Brien, 1993; Pashler, 1994b). These results indicated that attention was not held 'at capacity' across performances, as previously believed. Therefore, this theory is impractical for predicting degree and direction of attention.

Both limited-capacity theories rely upon dual task activities to compete for the same 'channels'. These theories also assume that for interference to occur, competing activities need to be similar (Pashler, 1994a). Similar tasks are not defined on what sort of operation is to be carried out but on what type of content of the information that is actually being processed. Simply, similar tasks compete for the same "mechanism" or "channel" need to decode what sensory inputs are present, what responses are being produced, what thoughts the person is having, etc. When tasks are dissimilar (i.e., they do not compete for the same "mechanism" or "channel") then interference effects are less likely to occur (Navon, & Miller, 1987).

Typically, similar tasks used in neuropsychological research have been: tapping while speaking (Simon & Sussman 1987), or balancing a

dowel with one hand and speaking (Kinsbourne & Cook, 1971).

Kinsbourne defined similar task not based on a "mechanism" or "operator" but as two tasks that compete for neural space in order to be processed. Competition for the same cerebral space in turn creates interference between tasks. Conversely, dissimilar tasks do not compete for same neural space (i.e., they can be processed separately without overlapping neural interference; Kinsbourne & Hicks, 1978). For example, Hirst and Kalmar (1987) had subjects monitor dichotically presented speech consisting of sequences of words, letters, or numbers on each channel. One of the subject's tasks was to verify that each number in a sequence was equal to the previous number plus two. When the same type of task was completed on both channels (e.g., verifying one number sequence on the left and another on the right), subjects experienced more interference effects than when a different task (e.g., verifying a number sequence in one ear and a letter sequence in the other) was performed on each channel.

In summary, these limited-capacity models were derived from experiments where the competing tasks were highly similar (Pashler, 1994a). Limited-capacity theories are not proficient for explaining the

processing of highly dissimilar tasks. These models assume that any limitations in performance is due to the limited capacity of a mechanism (i.e., channel) and not, in part, due to the operator themselves. Allport, Antonis, and Reynold (1972) introduced the concept of a multichannel processor model, where exceedingly different tasks are performed in parallel independence and interference occurs through the fault of the 'operator'.

Multichannel processing. Unlike the limited-capacity theories, which applied to concurrent use of the same mechanism, multichannel theory utilized separate mechanisms. Evidence for separate mechanisms came from experimental findings where concurrent performances of unrelated dual tasks performances did not typically overlap with one another (cf., Allport et al, 1972). In fact, dual task performances by subjects are virtually unaffected by one another. The ability to perform without a capacity restriction is clearly a function of dissimilarity between tasks.

The multichannel model uses an analytic device that distributes dissimilar inputs to disparate channels. The inputs are then held in a rapid-decay sensory register, after which the inputs are encoded

discretely between channels. These independent parallel outputs are either covertly acted upon or retained in long-term memory for later retrieval (Allport et al, 1972). Thus, this model implies that performance limitations (i.e., interference) are attributable to the function of the operator (i.e., subject) and not to any particular limited-capacity mechanism.

In summary, strict capacity limitation models involved tasks that arguably compete not only for performing similar activities but also for the use of the same mechanism in the brain. Thus, limited capacity may be applied within a 'mechanism' (Navon & Gopher, 1979). In contrast, when competition for a mechanism is disposed of, the limited capacity is also similarly disposed. This suggests that limited attention given to dual task performances involves the 'operator' rather than a 'mechanism'.

Strong empirical support for the dual task interference phenomenon came from single-channel research which suggests that interference is due to a 'mechanism' rather than the 'operator' (Kinsbourne, 1981). The multichannel processor lacks the ability to explain sufficiently why similar tasks hinder performances during concurrent task processing. Signals in different modalities, responses by

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voice and by hand, and coding in visual and verbal mode lend themselves more readily to a multiprocessing account than did conditions under which modality, coding strategy, and response mode are very alike for the two ongoing performances. Therefore it is the prominence of task 'similarity' as an organizing principle that naturally emphasizes some sort of device by means which divided attention could exert its effect – interference.

Functional Cerebral Space.

At the behavioural level, it is unduly simplistic to model the brain, a highly complex neurally linked system, after these limited-capacity theories. To attribute to the brain a limited overall capacity ignores its differential organization. To credit it with multiple capacity processors would totally miss the point of the brain's essential neural inter-connectiveness. Therefore, it is necessary for a different model to be created, a model that would capture the essence of attention in a neurological framework.

Kinsbourne and Hicks (1978) presented a theory that provides a better reflection or measure of the interconnectedness and functional organization of the neurological systems in the brain through the use of

the dual-task model. Their 'Functional Cerebral Space' (FCS) theory was contrived from carefully selected known facts about cerebral systems and their integrated workings as functional units. They operationally defined 'functional cerebral distance' (FCD) within the FCS model as,

"...concurrent activities that maximally coordinate when correlated, and maximally conflict when unrelated, would be closely adjacent within that topological space, and vice versa" (Kinsbourne & Hicks, 1978, p.347).

The idea for operationally defining FCD within the FCS model this way is a necessary transition needed to extrapolate FCS to Topological Cerebral Space (TCS). Topological cerebral space deals with the graphic delineation of the many relative positions and elevations of the areas within the brain. For example, clinical data suggests that for the majority of right handed people the left-hemisphere (TCS) contains the primary motor-control centre for speech and the primary motor-control centre for the right hand (For a review see; Springer & Deutsch, 1989; Iaccino, 1993; Kandel, 1991). The left hand has its primary motor-control centre in the right-hemisphere (TCS). According to the FCS model the programming of a right hand motor control centre would resonate one type of rhythm while the concurrent neural programming for the language

centre would resonate another. The incompatibility between these rhythms creates interference and right hand performance would decrease. The left hand's neural locus of control and the concurrent vocal control locus are functionally more distant in cerebral space so that their programming rhythms will not overlap. This allows for the left hand's performance and concurrent speech to go virtually unscathed.

Regardless of how separate the neural loci are for programming both tasks concurrently, most people cannot act out two disparate rhythms at the same time (Kinsbourne, 1978, 1982). In the example above, the task similarity was that both tasks (i.e., speaking and hand performance) called for the pulsation of separate neural rhythms. Neural 'cross talk' (i.e., interference) occurred between the voice and right hand motor-control centres when both rhythms are concurrently performed. But why should the pool of neurons that programs a voice rhythm be thought to 'overlap' with that control centre which programs a limb rhythm? This certainly is not what the FCS model would predict. Rather, the FCS model would predict that activity for each locus of programming irradiates, and interference occurs as neuron groups in the two loci attempt to resonate to the other rhythm while generating their own. When the two

loci are able to synchronize their resonating rhythms, we would then consider the tasks to be habituated or 'automatic' (Kinsbourne, 1981; Kinsbourne & Hicks, 1978). In other words, performance of concurrent familiar tasks become automatic or habituated when the synchronized neural rhythms require less attention to be distributed between tasks.

Functional cerebral space is a theoretical concept created to explain attention as a function of related distances between cerebral loci, and their functional neural interconnectedness. This theoretical conception of attention based on neurology provided Kinsbourne and Hicks with the ability to theoretically discuss and conceptualize FCS as the degree to which functional cerebral loci are interconnected (i.e., total cerebral area used) and related to the distance between these functional cerebral loci. The functional cerebral space model provided a better pragmatic and theoretical comparison between neural interconnections and existing cerebral topological space.

Functional Cerebral Space: The Theory.

Cerebral topology of the brain can be imagined as a specialized complex network of thousands of individual units, called neurons, and their interconnections. The performance of the brain underlies not only

relatively simple motor behaviours such as walking, breathing, and muscle flexing, but also elaborate affective and cognitive behaviours such as feeling, learning, and thinking (Kandel, 1991). Corresponding with each pattern of behaviour is a specific pattern of neural activity. Certain neural network activities are represented differently in different parts of the cortex, which generate neural firing patterns refined by experience for specific cerebral networks. According to the FCS model, every person has a certain amount of functional cerebral space which contains many complex and highly interconnected neural networks (Kinsbourne, 1982). For any particular motor-task a person performs, there is a corresponding program (i.e., a rhythm) located at a particular cerebral locus along with some spreading neural action. Neural spreading occurs as a by-product of the cerebral locus being programmed. Neural spreading refers to activation of other highly interconnected cerebral locations that results from the principal cerebral loci neural programming. In other words, the programming of a cerebral locus is not confined to a certain area within the cerebral hemisphere, but activation and concurrent programming of a neural locus would also activate other highly interconnected areas throughout the cerebral

hemispheres. Together the programming of the cerebral locus by a single input, and the neural spreading created by this input, consumes a sizable amount of cerebral space

The functional cerebral space model also states that new or novel inputs would consume quite a sizable amount of cerebral space, while previously experienced (i.e., habitualized) input would take less cerebral space. People typically can function by either using large amounts of cerebral space when providing their full attention to an anxiety-ridden task or using smaller amounts of cerebral space with more familiar task inputs where less attention is required. Situations where novelty to a task is involved creates the best situations for measuring attention effects. The dual task model is the needed ingredient for testing interference.

Dual-Task Interference. Programming a second discordant activity also involves a certain amount of cerebral space. For interference to occur, the programming of an discordant secondary motor-task has to co-occur within the same boundaries of cerebral space as the existing primary language-control centre. Therefore, motor overflow of the primary and secondary tasks within the same parameters creates a 'cross-talk' contamination (i.e., interference) between tasks (Kinsbourne

et al, 1978). The functional cerebral space model states that the closer these unrelated programmed areas are to each other, the more inclined the primary resonating neural rhythms would become disturbed by 'cross talk' from the other subordinate tasks unsynchronized rhythms.

Conversely, the greater the functional distance between the programmed loci, the smaller the probability that interference would occur. Less 'cross talk' would allow a person to perform both tasks simultaneously and sometimes with relative ease. These distinctions between functionally distant and close loci arrangements are essential to the groundwork for Kinsbourne and Hick's (1978) FCS theory, realizing that cerebral space is a function of neural interconnectedness and not based entirely upon brain morphology.

Two tasks related to dual task interference and to this study are vocal and manual tasks. How these tasks relate to the FCS model are discussed next.

Vocal-Manual Interference. The FCS model predicts that when the motor-centres for voice and the right hand (i.e., the motor centres in the left-hemisphere) are concurrently activated and engaged in unrelated activities, there would be greater interference between the voice and the

right hand control centres than between the voice and left hand control centres. The motor overflow (i.e., cross talk) that occurs created excess interference that could be expressed in three possible ways: 1) by greater decrement in the efficiency of right hand performance (Kinsbourne, & Cook, 1971; Hicks 1975), or (2) loss in the efficiency of vocal performance (Hicks, Bradshaw, Kinsbourne, & Feign, 1978), or (3) by both tasks being affected through the combined concurrent vocal and right hand performances (Kinsbourne & Cook, 1971, Kee & Cherry, 1990; McBride, Cherry, Kee, and Neale, 1994; Hiscock & Kinsbourne, 1980; Hiscock, Kinsbourne, Samuels & Krause, 1985; Inhoff & Bisiacchi, 1990; Keefe, 1985). Most of the research supports the latter statement, that more interference occurs through the combination of concurrent vocal and right hand performance in subjects who are right handed (Kee, Bathurst, & Hellige, 1983).

Many neuropsychological researchers have supported the FCS model using the dual task methodology. However, not all are satisfied with these results. Some (notably Willis & Goodwin, 1987) tend to doubt the authenticity of the model by focussing on the rather common methods used for measuring interference effects, which indirectly reflects upon the

legitimacy of the FCS model.

Critics of Neurological Dual Task Methods: Reflection on the FCS Model.

In 1987, Willis and Goodwin suggested that neuropsychological evidence for Kinsbourne and Hicks' (1978) FCS model was primarily flawed by the failure to address the 'initial-values' issue. This issue referred to the choice of measures (i.e., interference indexes) used for analysing differences between raw inter-hand scores generated through the dual task model. They claimed that measurements used to analyse inter-hand differences were relatively insensitive to lateralized interference effects. Research participants are usually right-handed and tapping rates typically favour the right-hand in the baseline condition. Therefore, these pre-existing hand differences would influence the sensitivity for detecting lateralized interference effects. Given this initial hand discrepancy, differential interference effects between hands associated with the concurrent performance of a task may be due to 'initial differences' (i.e., baseline) in tapping speed rather than lateralization of function effects. This means that, for right handed subjects, the right hand has an advantage over the left hand for producing more taps in the baseline condition, which gives the right hand a larger

potential range between conditions (i.e., baseline and dual task conditions), regardless of any lateralized functions. It is this discrepancy between hands in the baseline pretest condition that masks any possibility for detecting any lateralization of function effects.

Therefore, Willis and Goodwin (1987) conclude that empirical neuropsychological evidence for lateralization interference effects, generated through the dual task model, actually supports a false conclusion: that asymmetrical interference effects are actually a function of 'initial' hand differences and not lateralized cerebral function.

According to Willis and Goodwin (1987), the flaw with research on lateralized interference effects was not necessarily with the FCS model, but with the use of 'interference indexes' to measure these effects. A popular 'interference index' used by neuropsychologists and heavily scrutinized by statisticians is the 'Change score analysis' (CSA) approach.

General Problems With Using Change Score Analysis (CSA).

The typical interference index is a proportionate reduction in tapping rate. The primary proportionate equation originally used by Kinsbourne and Cook (1971) was: $R_1 - R_2 \div R_1 = x_1$, where x_1 is an

individual's interference index; R_1 is the subject's tapping rate for either right or left hand in the control (i.e., baseline) condition; R_2 is the tapping rate for the same hand in a dual task condition. Multiplying x_1 by 100 gave the 'percentage interference index' tapping rate score.

The numerator of the interference index is a 'Change score'. As other statisticians had pointed out (e.g., Lord, 1967; Linn & Slinde, 1977; Lacascio & Cordray, 1983; Willis & Goodwin, 1987), Change scores generally have statistical limitations with their utility: (1) Significant correlations between pretest, post-test difference scores, (2) confounded with measurement errors and (3) low reliability scores. These problems are discussed in more detail below.

Problem with Correlations Between Pre-and Post-Test Measures.

One of the most prevalent arguments for using 'Change score' indexes, instead of raw-score tapping rates, is that these types of indexes are assumed to be unquestionably independent of baseline and dual task tapping rates. However, research findings with notable correlations (e.g., Hiscock & Kinsbourne, 1980) and remarkable magnitudes occurring between pretest, post-test and different scores caused a great concern. For example, Willis and Hynd (1987) found that simple correlations

between the baseline scores and 'Change' scores ranged from 0.32 to 0.51 for the left hand and 0.23 to 0.41 for the right hand. This indicated that the magnitude of the correlation is largely an artifact of sharing the same initial values measurement errors and interference indexes (Willis & Goodwin, 1987).

From a statistical frame of reference, Change or difference scores (D_j) usually correlate with pre-and-post test scores (Willis & Goodwin, 1987). This is because the typical correlation between the pretest and the Change score (R_{xjdj}) is positive. As a result, high baseline tapping values are usually associated with large proportionate reductions in tapping rates during concurrent-task conditions. Conversely, low baseline tapping values are also associated with undignified proportionate levels of reduction during the dual task. Therefore, the magnitude of R_{xjdj} may be largely an artifact of sharing the same measurement errors in the baseline values and difference scores.

Also, from a statistical frame of reference, CSA is just as susceptible to other problems associated with repeated measure analyses. CSA designs, like repeated-measures designs, suffer from a serious disadvantage in that the validity of the F-ratio rests on

assumptions that are often not met. The problems stem from the fact that, unlike the completely randomized designs, the residuals in repeated measures designs tend to be interrelated because the same subjects are measured repeatedly. Nevertheless, when certain conditions are met, the F-ratio is still valid. A sufficient condition for the validity of the F-ratio is the case where the covariance matrices possesses the property of compound symmetry (Pedhazur, 1982), meaning that when the variances of all the variables within a group are equivalent. To relate this to the dual task model, when the variability within the baseline and dual task condition are not significantly equivalent, the error term is inflated, and the probability of not rejecting the null hypothesis increases. On the contrary, when the variability within the baseline and dual task conditions reflects that of the between groups variability, the error term is then properly adjusted for and the probability of rejecting the null hypothesis decreases.

Measurement Error. Measuring a subject's performance based on a score at one point in time and then again at another point only introduces multiple confounds between the pretest and post-test periods. These confounds could be due to inconsistent measurement units

between pre-and post-test periods (Linn & Slinde, 1977). For example, two tests may be given (i.e., one for the pretest and the other for the post-test), but sometimes the units of the two tests will be unequal, as when an item that measures problem-solving skill at one point in time may measure memory at a later point in time. Not considering the anomalies that influenced the measurements differently at different periods in time may incorrectly lead researchers in committing a type I error (Pedhazur, 1982). That means these anomalies create an artificial inflation in the residual variance for each measurement period which, in turn, creates a larger probability for the F-ratio to be rejected.

Low reliability. The difference score (D) between X1 and Y1 is a function of the reliability of the pretest score (X1), the reliability of the post-test score (Y1), and the correlation between X1 and Y1 (Lord, 1967; Linn & Slinde, 1977; Willis and Goodwin, 1987). The formula for obtaining the reliability of D is typically manifested as; $\rho_{DD'} = \rho_{XX'}\sigma_x^2 + \rho_{YY'}\sigma_y^2 - 2\rho_{XY}\sigma_x\sigma_y / \sigma_x^2 + \sigma_y^2 - 2\rho_{XY}\sigma_x\sigma_y$, where $\rho_{XX'}$ and σ_x^2 are the pretest reliability and variance, $\rho_{YY'}$ and σ_y^2 are the post-test reliability and variance, and ρ_{XY} is the correlation between the pretest and the post-test.

Usually an inverse relationship existed between the value of the reliability coefficient for the difference scores ($\rho_{DD'}$) and the correlation between pretests and post-tests (ρ_{xy}). As ρ_{xy} grows larger the reliability ($\rho_{DD'}$) will deflate to a discouraging low (Linn & Slinde, 1977).

Consequently, in order to obtain a more reliable Change score, a low correlation between pretest and post-test scores is needed. A problem with low correlation's between these scores is whether the pre- and post-measures are measuring the same construct. Measuring the same construct would seem to be a prerequisite for the difference score to be interpreted as an index of growth (i.e, a Change score!).

Therefore, the Change scores typical low reliability might deceive the analyst into making a risky decision about individuals on the basis of change from pre-to post-testing periods. In other words, the temptation for most scientists to conclude that interference actually occurred appeared to be far greater, that it overrode the deception of low reliability D scores (i.e., that interference did not occur).

The problems with Change scores have lead others, such as Willis and Goodwin (1987), to seek alternatives in measuring differences between hands. One common alternative is to find a Change score that

has a zero correlation with the pretest score (Linn & Slinde, 1977, Klockars, 1992). Such an alternative provided greater potential to address the 'initial values' problem more effectively by using an analysis of covariance (ANCOVA).

Corrective Measures To Address The 'Initial Values' Issue.

Ordinarily, in a dual task group designs the initial difference values have a non-zero correlation between the pretest and treatment effects. These pre-treatment differences then make the interpretation of any difference between groups on the post-test problematic. At issue is low baseline hand differences may effect change scores in the absence of asymmetric (dual task interference) effect.

Kenny (1979) suggested four statistical modes to measure treatment effects in nonequivalent group designs: 1) Analysis of covariance; 2) Analysis of covariance with reliability correction; 3) Change score analysis (CSA); 4) Standardized change score analysis.

Modes 1 and 3 are discussed in the next section below, while modes 2 and 4 are discussed in the converging results with ANCOVA and CSA procedures section below.

Traditional CSA and Traditional ANCOVA (Modes 1 & 3). It is

possible to achieve a zero-order correlation between the pretest and the 'residual' scores using 'residual' scores from the baseline condition. This can be seen as a major advantage over gain scores (see Linn & Slinde, 1977, for a review on this literature). Residual values do not give an advantage to persons with preexisting baseline values on the pretest measure (i.e., this is done by partialling out the baseline hand difference), whereas CSA procedures did. Clearly this is viewed as a possible major advantage for using ANCOVA over that of the CSA approach. Apparently this is what Willis and Goodwin (1987) believed. They stated that ANCOVA is the appropriate method to address the 'initial-values' as statistically controlling for the effects of the baseline values on subsequent dual task values. Therefore, ANCOVA procedures requiring dual task tapping rates, with initial baseline tapping rates used as covariates, are assumed to be a viable alternative approach to addressing the initial-values problem. Overlooked by Willis and Goodwin is the fact that using ANCOVA procedures does not always reap the reward that is assumed this procedure would do.

Logically it is assumed that using the ANCOVA procedure is primarily a better way to single out individuals who have gained more or

less than could be expected and not as a 'corrected' measure for the CSA approach. Why? Because, although ANCOVA does help to solve the problem caused by the correlation between 'change' and pretest scores, these residual scores, like gain scores, tend to be unreliable. Examining the formula for the reliability coefficient residual score; $pr' = \frac{p_{yy} - p_{xy}^2(2 - p_{xx})}{1 - p_{xy}^2}$, the correlation between the pretest and post-test (p_{xy}) scores increases and the reliability of the residual coefficient (pr') decreases. Low reliability is a primary disappointment to those allied with the idea that the ANCOVA approach is going to be a greater advantage over the CSA (e.g., Willis and Goodwin, 1987; Klockars, 1992).

Another strike against using ANCOVA, similar to that of CSA and repeated measures, is that the validity and assumptions of the F-ratio are often not met. A sufficient condition for the validity of the F-ratio is that the covariance matrices possess the property of compound symmetry (Pedhazur, 1982). This means that ANCOVA assumes that the within group regression slopes mirror that of the between groups regression slope. This assumption is typically violated because the measurement error (stated in previous section above) and trait instability of the within variance associated with the pretest and post-test measures are not

accounted for (Lacascio & Cordray, 1983).

Trait instability could be defined as the fluctuations in true values of a variable for an individual over time (Lacascio & Cordray, 1983). A correlation between the pretest and post-test measures of a variable for a group of individuals may be attenuated because of trait instability even though measurement of the variable at both time points was perfect.

When ANCOVA is applied to pretest and post-test data for preexisting natural groups, the slopes of regression lines may be attenuated because of trait instability and results of ANCOVA may then be biased just as they would be by measurement error. According to Lacascio and Cordray (1983) it is trait instability that is the primary source for affecting the within group regression lines, which in turn, does not affect the between groups regression line for group means.

If trait instability is increased it will cause the within-groups regression slopes to become steeper and reflect that of the between groups means. In other words, when trait instability is accounted for, the different within regression slopes should align together so that any score on the post-test (y) is equivalent to the same score on the pretest (x) (i.e., the within groups regression slopes aligned together so that $y = x$).

Unfortunately, trait instability may also invalidate the results of the ANCOVA. Ordinary ANCOVA may be appropriate when selection into experimental groups is based on pretest scores but when it is used to analyse differential effects for preexisting natural groups, measurement error in the pretest and trait instability can bias the results (Kenny, 1979).

To summarize thus far, where the ANCOVA within groups regression slopes are unequal because of unequivalent pretest and post-test variances, ordinary raw score CSA is generally met with non-significant effects, whereas ordinary ANCOVA, when assumptions are met, will provide a small magnitude of effect. Regardless of the inherent problems with CSA, the results do typically provide small but significant magnitudes of effect. Again, these small differences are due to these inherent problems. Yet, these differences are still significant !

Therefore, it is logical to assume that reliability between different measures (e.g., CSA & ANCOVA) should reveal converging evidences for lateralized interference effects. Instead, typical results are generally found to fluctuate in a reciprocating significant-non-significant fashion.

A possible clue as to why different results typically occur between those researchers who have used CSA or ANCOVA procedures is to

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examine 'Lord's paradox' (see Lord, 1967 for review). Briefly, the paradox states that when using a set of pretest and post-test data for two or more treatment groups, different effects will emerge depending on the statistical technique employed to analyse the data. Although Lord's paradox may help to enlighten the phenomenon of non-convergent results between statistical methods, it does not help to explain what could be done about this phenomenon. Lord (1967) concluded that there apparently seemed to be no logical or statistical procedure that could be used to make proper allowances for uncontrolled preexisting differences between groups.

Since then, others such as Kenny (1979), Lacascio and Cordray (1983), Campbell and Boruch (1975) and Kee and Cherry (1990), have concluded that there are statistical and logical ways to control for preexisting differences.

Converging Results With ANCOVA and CSA Procedures (Modes 2&4).

Kenny (1979) recommended using a standardized CSA when pretest and post-test variances are unequal. The adjustment is made to the pretest scores by multiplying the ratio of the pooled within group post-test standard deviation to the pooled within group pretest standard deviation and then computing an ordinary CSA on these altered scores.

Whether pretest and post-test variance are equal or not, ANCOVA usually provides an unbiased assessment of natural group treatment effects that are not attributable to pretest differences if necessary adjustments are made (Campbell & Boruch, 1975). Campbell and Boruch (1975) recommended that when trait instability constitutes a source bias, that the simple within group pretest and post-test correlation should be used with the following within groups adjustment formula: $\bar{X}_j + r_{ij}(X_{ij} - \bar{X}_j)$. The r_j is the zero-order within groups correlation between the pretest and post-test for the j th group; X_{ij} is the pretest score for each subject within each group of the pretest variable; $\bar{X}_j$ is the separate pretest mean for each pretest group.

Lacascio and Cordray (1983) used Campbell and Boruch's (1975) suggestion for adjusting the within regression slopes in each pretest and post-test values and compared their results with that of the CSA method. They concluded that with the Campbell and Boruch adjustment, the ANCOVA and CSA results both significantly agreed.

Methodological Issues.

Kenny (1979) suggested that there are four models of statistical analysis to measure treatment effects in dual task designs. These four

modes of analysis have been discussed. Regardless of shortcomings with each mode of analysis, all four modes will be used for analyses in this study. The purpose for this is to show that modes 1 and 3 (i.e., regular ANCOVA and regular CSA) for measuring treatment effects should determine different results. The altered ANCOVA and the altered CSA (modes 2 & 4) should converge with significantly better results. Using both procedures will: 1) show converging evidences, unlike that reported by Willis and Goodwin (1989); 2) display that interference effects will occur as predicted by Kinsbourne and Hicks' (1978) FCS model, when appropriate assumptions and corrections are used, regardless of the implementations to the contrary.

The following dependent variables will be assessed: for the CSA method (mode 3), the percentage of change method originally used by Kinsbourne and Cook (1971) is used. Adjustments are made to the CSA formula (mode 4), as suggested by Kenny (1979). In the covariance analysis (mode 1) the pretest is the covariate and the post-test is the dependent variable. Appropriate adjustments (mode 2) will be made to the altered covariance as suggested by Campbell and Boruch (1975) and Lacascio and Cordray (1983).

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The primary independent variables in this study are as follows; Condition (Standard, Adjusted , and Exaggerated), Block (Baseline and Dual task), and Hand (right vs left). The conditions are chosen to replicate Kee and Cherry's (1990) design and an Exaggerated tapping condition was added to demonstrate effects of right hand interference even with a disadvantaged dominant hand. Each subject participated in only one Condition, but completed both Blocks. The Baseline block allows the pretest measures for each hand to be made without interference from another secondary task. The Dual task Block is where the subject performs vocal and concurrent finger tapping activities. The Dual task block allows for a measure of degree and magnitude that is created by the effect of interference that occurs because of competition for functional cerebral space.

In this study, handedness is a very important variable in that it allows for comparisons between preferred and non-preferred hands for each condition and comparison of hand performances between Blocks within each Condition. Determination of handedness was done by asking participants to fill out Oldfield's (1971) Edinburgh Handedness Questionnaire. It is anticipated that the preferred hand (i.e., right hand)

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would significantly out tap the non-preferred hand (i.e., left hand) in the Standard condition. I expected that there would be no significant differences found between hands for the Adjusted condition, and the right hand in the Exaggerated condition would actually perform worse than the left hand. In all three Dual task conditions (using the traditional CSA and altered CSA and altered ANCOVA) I conjectured that lateralized interference effects indicating left hemisphere speech dominance would be elicited, as expected by Kinsbourne and Hicks' (1978) functional cerebral space model. That is, it is expected that there will be greater interference from the verbal task during right hand tapping than during left hand tapping in all conditions using the regular CSA, and altered CSA, ANCOVA methods.

Adjustment to the Premeasure Variable. To control for premeasure confounds regarding the dominant hand, such as practice effects (Adams, 1981; Hicks, Provenzano, Rybstein, 1975), pre-existing differences between hands are taken into account through the methodological adjustment suggested by Kee and Cherry (1990). This adjustment counters the effect of the 'initial values' problem by eliminating any differences between hands in the Baseline Block. That is, the tapping key

is made more difficult for the right hand to use by adjusting the tapping key so that both hands are equivalent in their Baseline tapping speeds (McBride, Cherry, Kee, & Neale, in press; Kee & Cherry, 1990).

Effect, Power, and Sample Sizes. The magnitude of the traditional altered gain score effect between pre- and post-test measures is typically moderate-to-small (e.g., Kee & Cherry, 1990). Therefore, it is imperative in the present study to explore a large enough sample size to help ensure that a significant difference will be detected, given that there really is a "true" difference to be found. Keppel, Saufley, and Tokunaga (1992) offered the following guidelines to characterize effects sizes (ω^2) as follows: 1) a "small" effect produces an ω^2 of .01; 2) a "medium" effect produces an ω^2 of .06; and 3) a "large" effect produces an ω^2 of .15 or greater.

To determine an appropriate effect size Keppel, Saufley, and Tokunaga (1992) suggested examining the correlation coefficient between Hand and Blocks (See Keppel et al for further review). Based on pilot testing of 12 subjects the effect size was determined to be $\omega^2 = .044$. This effect size was then used in calculating the sample size needed. Setting the power level at .80 and the omega value at 1.85, it

was determined that a sample size of at least 74 subjects would be needed to detect a small to moderate ($\omega^2 = .044$) effect size (See appendix A for the effect and sample sizes formulas).

Individual Differences.

This section on individual differences discusses issues related to handedness and its' relationship to cerebral organization, which are important factors in the current study. Specifically, issues such as; determining hand preferences by questionnaire, the possible relationship handedness has with cerebral speech function, and gender differences related to cerebral organization, are discussed hereinafter (See Bryden, 1982; Seegalowitz & Bryden, 1983; and Corballis, 1983a, for a good literature review on these issues).

Measuring Handedness. By far the most common way of assessing handedness today (i.e., determining the dominant or preferred hand) is through a hand preference inventory. In such an inventory, a list of unimanual activities are compiled, and the subjects are asked which hand they prefer to use to carry out the activity (e.g., Crovitz & Zener, 1962; Oldfield, 1971; see Appendix B for and an example of the Oldfield (1971) Edinburgh Handedness Inventory). In the Oldfield inventory,

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subjects have to indicate which hand they prefer to use for each of 12 items (further details of this questionnaire are described in the methods section). The range of handedness scores go from +1.00 (strongly right-handed) to -1.00 (strongly left-handed). This inventory is the most widely used measure of handedness today.

The Crovitz-Zener (1962) questionnaire is not as widely used, requires subjects to mark one of six response boxes, labelled "Right hand always (Ra)," "Right hand most of the time (Rm)," "Use both equally often (E)," "Left hand most of the time (Lm)," "Left hand always (La)," and "Do not know which hand (X)." The items are scored on a 5-point scale. On items 1, 3, 5, 7, 8, 9, 11, 12, and 14 the Ra is scored "1"; Rm, is "2"; E, is "3"; Lm, is "4"; and La, is "5". Items 2, 4, 6, 10, and 13 are scored in the reverse fashion, because the strong right-hander normally performs these activities with the left hand. Scores range from 14 (strongly right handed) to 70 (strongly left handed). Hand preference is indicated by circling the appropriate response box for each of the following activities: 1) is used to write with, 2) to hold a nail when hammering, 3) to throw a ball, 4) to hold a bottle when removing the top, 5) is used to draw with, 6) to hold a potato when peeling, 7) to hold a pitcher when pouring out of it, 8) to hold

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scissors when cutting, 9) to hold knife when cutting food, 10) to hold a needle when threading, 11) to hold a drinking glass when brushing teeth, 12) to hold a tooth brush when brushing teeth, 13) to hold a dish when wiping, 14) holds tennis racket when playing.

Many difficulties with handedness questionnaires exist. One problem is with the subjects' choice of covert vs overt preferences for a given task. The activities asked about in the questionnaire differ in frequency from the actual hand with which subjects perform the activity and this may affect the reliability of the answer (Bryden, 1977). For example, the responses may not correspond to the behaviour manifested in real-life situations. In this sense, the item(s) may not have external validity.

An attempt by Bryden (1977) to refine the existing handedness questionnaires for validity, was done by administering both the Crovitz and Zener (1962) and Oldfield (1971) questionnaires to a sample of 1107 students. He used a 5-point scale for scoring the Oldfield test, assigning values from 1 for a "right ++" to 5 for a "left ++", similar to the marking scale of Crovitz-Zener inventory. This way he was able to keep similar measurement units between inventories. The analyses of 24 items (12

from Crovitz-Zener and 12 from the Edinburgh Handedness Inventory) extracted three factors. The first factor was a primary handedness factor that loaded on writing, throwing, drawing, using scissors, and using a toothbrush. The second factor was specific to the Crovitz and Zener questionnaire and included primarily those items that were reverse scored. This suggests that these reversed items appear to lead subjects into dubious confusion, when these items were actually designed to ensure that subjects would pay attention to the questions being asked. The third factor loaded primarily on items that were rare activities (e.g., striking a match, and opening a box lid). This suggested that the subjects had difficulty in visualizing the activity and that tended to be unreliable.

Handedness and Its Relationship to Cerebral Function.

Approximately 95% of the North American population is right handed (dextral), whereas about 5% can be classified as left handed (sinistral; Iaccino, 1993; Bryden, 1982; Segalowitz & Bryden, 1983). Why right handedness predominates is not clearly understood. Theories and explanations, such as the genetic model (Annett, 1964, & 1972), and pathological explanation assuming early damage to the left hemisphere (Hicks & Kinsbourne, 1978; Springer & Searleman, 1980), are a few of

the many theories which have been developed to explain why left handedness remains in our population, but in such a small number. For the present study's purpose, it is more important to note that handedness is probably related to lateralization of function in the human cerebral cortex. Handedness and its relationship to cerebral speech function is discussed below.

Dextrals and Sinistrals. It is generally accepted that cerebral organization of language function differs for sinistrals and dextrals (Murphy & Peters, 1994; Bathurst & Kee, 1994; Green, Steiner, & White, 1994). There seems to be an association between handedness and speech lateralization. For example, disturbances of speech following right hemisphere damage are more common in sinistrals than in dextrals (Segalowitz & Bryden, 1983), suggesting a shift in speech lateralization in this group. However, this relationship is not a particularly close one, since the majority of sinistrals, like the majority of dextrals, have left hemisphere language (Corballis, 1983b).

One way to investigate the relationship between handedness and speech function is to study a clinical population with language disorders (i.e., Aphasia; Iaccino, 1993; Springer & Deutsch, 1989). Bryden and his

colleagues (Segalowitz & Bryden, 1983; Bryden, 1982) estimated that about 62.1% of dextrals and 52.8% of sinistrals in the clinical literature were aphasic following unilateral damage to the left hemisphere. Conversely, 3% of the dextrals and 25.1% of the sinistrals were aphasic following unilateral damage to the right hemisphere. From the right handed population (i.e., which represent about 95% of the handedness population with left hemisphere language dominance) they estimated that 95.5% had left hemisphere speech and 4.5% had right hemisphere speech. Conversely, from the left handed population (estimated to represent about 5% of the handedness population with right hemisphere language dominance) they estimated that 61.4% had left hemisphere speech, 19.8% had bilateral speech, and 18.8% had right hemisphere speech. None of the right handed population had bilateral speech.

Another way to measure handedness and speech lateralization is to *anaesthetize* one hemisphere temporarily. Wada and Rasmussen (1960) developed a sodium amytal technique that 'numbed' portions of the cerebral cortex in a predictable fashion for a brief period of time. This made it possible to obtain data on the relation between handedness and speech lateralization. Their investigations revealed that approximately

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96% of dextrals and 70% of sinistrals showed left hemispheric speech lateralization. Right hemisphere speech lateralization is more common in sinistrals (15%) than dextrals (4%). Although none of the dextrals portrayed bilateral speech lateralization, and approximately 15% of the left handed population did. These results are also comparable with the above reported clinical aphasic population proportions for handedness and left-and right-hemisphere language dominance.

Bathurst and Kee (1994) investigated cerebral function of speech in a non-clinical population of sinistrals using the dual task method (which has the advantage of being non-invasive). The primary task was manual tapping. Subjects had to solve verbal anagrams silently or aloud as one of their secondary tasks. The other secondary task was a nonverbal task involving Raven's Progressive Matrices. The concurrent performance of the verbal and nonverbal tasks revealed the typical asymmetric manual performance indicative of left hemispheric language for dextrals. In contrast, the verbal and nonverbal conditions for the sinistrals showed no asymmetric interference patterns, but rather a percentage decrease in both hands performance which suggested to the authors that there was bi-lateralization of language functions.

Since sinistrals are an intriguing population, other methods have been used to investigate their handedness relationship to speech lateralization, such as familial history of sinistrality (Zurif & Bryden, 1969), strength of handedness (Annett, 1972), dichotic fused rhymed word test (Wexler, Halwes, 1983) and writing hand position (Parlow & Kinsbourne, 1981; for a good literature review on these methods see Bryden, 1982). Results from these methods are less conclusive than what clinical data suggests (Corballis, 1983b).

In summary, sinistrals generally show a higher incident of right hemisphere and bilateral speech representation than do dextrals. Attempts to predict just which sinistrals have right hemisphere speech have not been successful (Corballis, 1983b). It may, however, be considered that on average, dextrals are more likely to be strongly lateralized for speech than sinistrals.

In the present study, it is important to have a homogeneous sample (Group B), so that any effects of condition on scoring is not due to different hemispheric lateralization of function of speech. Data analyses were performed on subjects who tested for the following: 1) left hemisphere dominance for language. Determination of left hemisphere

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language dominance is done by a dichotic listening test developed by Wexler and Halwes (1983). Although lateralization is less clear for this test in non-clinical populations than it is in clinical sample, it is noninvasive and represents an alternative method to dual-task procedures to establish lateralization of speech. Wexler and Halwes (1983) reported that this test has a test-retest reliability coefficient of .85 and is able to classify right-handed subjects with left hemisphere speech (i.e., subjects with a left ear advantage) approximately 85% of the time. I chose this dichotic listening test to be used in the present study because of its reliability and validity for defining hemisphere dominance for language. 2) Right hand preference as determined by the Edinburgh Handedness Questionnaire (see Edinburgh Handedness Questionnaire procedures in the methods section below).

The clinical data claims (e.g., Bryden, 1983) that approximately 95% of right handed people have left hemisphere speech. Since, these studies do not distinguish which of the right-handed individuals have left hemisphere speech, a heterogenous sample (Group A) representing right handed subjects with high and low dichotic listening values is used. Selection for this group was in this order: 1) Subjects had to have a right

hand preference, as determined by the Edinburgh Handedness Questionnaire. 2) From those selected with a right hand preference, an arbitrary dichotic listening value was chosen to represent about 95% with left hemisphere speech dominance.

Gender Differences. Within the realms of neuropsychological lore, males are thought of as being more left-lateralized for speech and females to be less lateralized with regards to speech dominance (See Segalowitz & Bryden (1983); Bryden, 1982; McGlone, 1980; for reviews of the literature). For example, McGlone (1980) administered the WAIS to adult subjects following stroke or tumours confined to one hemisphere. She found that left hemisphere damage in men lead to a more significant decrement in Verbal IQ relative to Performance IQ, while no similar difference was found for the women. Also, right hemisphere damage lead to a significant Performance IQ deficit in men, but not in women. She concluded that men were more lateralized for left hemisphere speech, while women were less lateralized.

Others (e.g., Segalowitz & Bryden, 1983) have failed to support McGlone's (1980) results. They argued that there were no significant differences between males and females IQ for verbal (VIQ) and

performance (PIQ) tests after unilateral brain injury. Possibly, different results occurred because of problems with the clinical populations used. Problems such as not knowing how much of the deficit in VIQ and PIQ was attributable to the patients' brain damage, prior to commencing treatment. Another problem maybe that the details of how each subject performed the tasks was not recorded. Therefore, subjects could successfully accomplish behavioural tasks in a variety of different ways, and there is normally no way of knowing what strategy a particular subject used on a particular occasion.

The point is, if men and women adopt different strategies for performing a particular task, it becomes unclear as to whether or not task performance is attributable to sex differences in laterality of speech or to differences in the strategy employed. Bryden (1982) suggests that for this reason it is particularly important to fully understand the experimental task being employed and to attempt to control individual differences in strategy.

The dual task model has been used to address the issue of sex differences for lateralization of speech. Ashton and McFarland (1991) tested 648 females and 301 males who were all right-handed. The tasks

were tapping (i.e., tap as fast as you can) paired with a concurrent verbal task. The participants were to tap with a pen between two crosses printed 6 cm apart on a sheet of paper. They were told to attempt to tap with the pen on one cross with each tap, but to alternate between the two crosses as fast and accurately as possible with each hand separately. Then they were asked to tap while concurrently repeating aloud tongue twisters. They found the expected right hand effect (indicating left hemisphere speech) predicted by the FCS model, but did not detect a sex difference.

Therefore, for the purpose of the present study, it was hypothesized that right-handed males and females would have similar cerebral organization for speech function. The non-significant variability found between the sexes would be pooled together into the error term. However, gender differences on performance of the secondary task may differ between genders. Therefore, the effect of the verbal task as a function of gender was tested with the analyses that follow below.

Secondary Tasks: Effects on Performance.

Typically, in Kinsbourne and Hicks (1978) dual task model, the primary task is tapping. The secondary task is usually a cognitive task,

such as nursery rhymes (e.g., Hiscock, Kinsbourne, Samuels & Krause, 1985), animal naming (e.g., Kinsbourne & McMurray, 1975), anagrams (e.g., Cherry & Kee, 1991), and tongue twisters (e.g., Hiscock, 1982). Kinsbourne (1981) explained that the more difficult the secondary task is the greater the probability that there will be interference and therefore the expected dominant hand effect will be elicited. A brief review of this literature follows below.

Researchers have investigated interference effects produced by Dual task methods as a function of hand dominance (e.g., see Cherry & Kee, 1991; Simon & Sussman, 1987; for a reference). In these studies, the primary task is to have the participants tap as fast as they could. The secondary task is either to solve anagrams (Cherry & Kee, 1991) or describe a picture, read aloud, or speak candidly (Simon & Sussman, 1987). Left- and right-handed subjects had their dominant and non-dominant hand tapping rates tested separately for a baseline measure. Also, each subject was tested for hemisphere specialization of language using a dichotic listening method. After analysing all the interactions between both manual hand performances and hemisphere language, they concluded that Dual task interference effects found in the concurrent

primary and secondary tasks were due to activation of both hemisphere lateralization of speech locus and the dominant hand motor locus.

Regarding the literature that uses tapping as the primary task, the specific effects of different secondary tasks on the dominant hand interference is difficult to find. But, if comparisons are made between a variety of neuropsychological experiments that use tapping as the primary task and different secondary cognitive tasks, it might bring some insight into the effects that these secondary tasks have on interference. Some of the more common secondary tasks in the literature are nursery rhymes (e.g., Hiscock, Kinsbourne, Samuels & Krause, 1985), animal naming (e.g., Kinsbourne & McMurray, 1975), anagrams (e.g., Cherry & Kee, 1991), and tongue twisters (e.g., Hiscock, 1982).

In experiments that use nursery rhymes, animal naming, or anagrams as their secondary task, the typical influence of the task tends to only produce a relatively small interference effect. For example, Hiscock and Kinsbourne (1981) used nursery rhymes and animal naming tasks as separate secondary tasks on children. The approximate mean percentage change for subjects with left hemisphere language and right-hand dominance in the Dual task condition ranged from about 5.7% for

nursery rhyming to a decrement value of 5.6% for the animal naming task.

Kee and Cherry (1990) used anagrams as a secondary task. The mean percentage decrement between the baseline and dual task tapping rates for dextrals by condition (i.e., Standard vs Adjusted) varied from 4.27% to 5.37%, respectively. The Standard and Adjusted conditions in their experiment are replicated in the present study with an extra condition added (i.e., the Exaggerated condition).

To check my procedures to see that right hand interference effects were elicited, and were of suitable size, as well as to identify any possible problems related to the secondary task, piloting was done using two different verbal tasks.

I looked at the performance of 10 right-handed subjects tested using anagrams as a secondary task. The mean percentage Change in tapping was considerably less (4.23%) for the right hand than for the left hand (12.4%) in the Standard condition. This was unexpected. In the Adjusted condition a left hand effect (14.1%) was also observed to be greater than the right hand effect (5.25%). The Exaggerated condition had a right hand decrement value of 7.4% and the left hand's decrement (-4.5%) was not a decrement but a increment. Why an increment

occurred is not fully understood. This may reflect the fact that subjects were not screened for hemisphere speech dominance or handedness preference.

A different secondary task (tongue twisters) was then examined. Hiscock (1982) used the tongue twister task and reported much larger interference effects with finger tapping used again as the primary task. I have found relatively larger interference effects. The decrement in tapping rate, relative to the baseline in his study, was greater for the dominant right hand (32.1%) than for the left hand (25.1%).

I found the mean percentage decrement when tongue twisters were used in a sample of 12 right handed subjects was 16.14% for the right hand and 11.8% for left hand in the Standard condition (i.e., the condition where subjects baseline tapping rates are greater for the dominant hand than for the non-dominant hand). In the Adjusted condition (i.e., where both hand's baseline tapping rates are similar to one another) the dominant right hand had a greater percentage decrement of 25.4% and the left hand decreased by 12.1%. The Exaggerated condition (i.e., where the dominant hand's baseline tapping rate is less than the non-dominant hand's rate) produced a right hand

decrement of 9.25% and a 29% left hand decrement value in this sample.

Because the tongue twisters produced a larger interference effect, this task was selected for use as a secondary task in the present study.

Hypotheses.

For each hypothesis that follows, similar outcomes are predicted to occur for three of the statistical analytical procedures used (i.e., 1) Traditional CSA, 2) Altered CSA, and 3) Altered ANCOVA procedures). The traditional ANCOVA analyses conclusions should be comparable to Willis and Goodwin's (1987) results. That is, it is predicted that the results for this analysis will not find a hand interference effect. The hypotheses below are also based on the assumption that all subjects are right handed and have left hemisphere language dominance (as described in the handedness section above).

Statistical Analyses Hypotheses.

In the literature, where different methods for measuring 'change scores' are used (i.e., CSA or ANCOVA), different results typically occur. For example, Kee and Cherry (1990) used the traditional CSA approach and found a right hand interference effect in a dextral sample. In contrast, Willis and Goodwin's (1987) traditional ANCOVA did not find a Hand

effect.

However, no one has yet in this literature considered using an altered analyses for both the CSA and ANCOVA methods.

The independent variables in the design are: Conditions (Standard, Adjusted , and Exaggerated), Block (baseline and dual task), and Hand (right vs left hands). The dependent variable for the traditional CSA analyses is the "percentage of change" method. For the traditional ANCOVA analysis, the pretest is the covariate and the post-test is the dependent variable. The altered CSA depended variable is also the percentage of change, but with the appropriate adjustments made as suggested by Kenny (1979). The altered CSA method adjusted the baseline score for each hand separately by taking the pooled baseline standard deviation divided by the pooled dual task standard deviation and multiplying this result by the baseline score to get a new separate baseline score for each hand. Appropriate adjustments are made to the each hand's pretest in order to make the altered ANCOVA as suggested by Campbell and Boruch (1975) and Lacascio and Cordray (1983). Here the adjustments are made in accordance to the condition in which the subject participated. A simple correlation for the hand between the

baseline and dual task values multiplied by the difference between the baseline hand score and the mean for the condition. This result is then added to the condition mean and a new altered baseline value is created for this hand.

Four possible outcomes are predicted for each of the four analytical modes (i.e., traditional CSA and ANCOVA and altered CSA and ANCOVA methods) used in this study. The first two hypotheses predict, based on results found in the literature, that separate diverging outcomes will result. The last two hypotheses predict that converging results between analyses will occur when the altered methods are used. Converging significant results between analytical procedures will provide consolidating evidence for the usefulness of the FCS theory in neuropsychological research.

Hypothesis 1. It is predicted that the traditional CSA method will give a small, but significant percentage of change between hands for subjects with left hemisphere language and right-hand dominance, similar to that of Kee and Cherry's (1990) results. Specifically, a small but significant interference effect will occur in the direction of the right hand tapping slower than in the left hand as predicted by the FCS (1978)

model.

Hypothesis 2. The traditional ANCOVA procedure will result in a non-significant percentage of change between hands for subjects with left hemisphere language and right hand dominance, similar to that of Willis and Goodwin's (1987) conclusions. That is, the traditional ANCOVA results will be non-significant for interference effects between hands for subjects who are right handed and left hemisphere language dominance.

Hypothesis 3. The altered CSA procedure will detect significant right hand interference effects between for subjects with left hemisphere language and right hand dominance. This procedure will account for more variance in the dependent variable than that found by the traditional CSA or ANCOVA methods.

Hypothesis 4. The altered ANCOVA method will also detect significant right hand interference effects in subjects with right hand dominance and left hemisphere specialization for language. This procedure should also account for more variance than found by the traditional CSA and traditional ANCOVA.

Secondary Task Hypothesis.

Hypothesis 1. It is predicted that the speech output for right

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handed subjects and across all three Conditions would be significantly less while tapping with the right hand than tapping with the left hand.

Hypothesis 2. It is predicted that speech output while speaking alone would be greater than speech output during concurrent tapping and speaking.

Methods

Design and Subjects.

The design is a 3 (Conditions: Standard, Adjusted , and Exaggerated) x 2 (Gender: male vs female) x 2 (Blocks: baseline vs dual-task) x 2 (Hand: left vs right) mixed factorial design. All factors were manipulated as repeated measures with the exceptions of Gender and Conditions which are completely randomized factors. Although there were no gender tapping differences expected, it was not known whether there would be any gender differences on the secondary (tongue twister) task. Therefore, gender was added to the following analyses.

Seventy-one Carleton University introductory psychology students, ages 18 to 32 years old from Ottawa, Canada, participated and received academic credit towards a first year introductory psychology course. Thirty males and Forty-one females were be quasi-randomly assigned

among the three conditions (Standard, Adjusted, Exaggerated).

Materials

Based on Kee and Cherry's work (1990, and 1994), the speed of tapping on a micro-switch apparatus varied depending on two criteria: (1) the operating force, and (2) the travel-distance. Operating force (O.F.) was the force required to press the lever of the switch down with the index finger until the switch turns from the "off" to "on" position. The present experiment varied the O.F. across the three conditions. The O.F. of each condition, force was measured using a spring scale ranging from 0 to 30 ounces. Travel-distance (T.D.) was the distance the subject had to move their index finger down from a reference bar to complete depression of the switch in the "on" position (See diagram in Appendix C of reference bar on the tapping apparatus).

A 15 Amp Micro-Switch model no. BZ-2RW84-A2BZ-2R-A2 with an O.F. of one ounce was used to record the left hand's finger tapping in all three conditions and the right hand's finger tapping in the Standard condition. A second 10 Amp micro-switch (model DT-2RS1-A7) was used by the right hand in two conditions (Adjusted and Exaggerated) had an operating force that ranged between 12 to 20 ounces.

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Both micro-switches were mounted seven centimetres apart on a 36 cm x 20cm x 6 cm (L x W x H) wooden box and connected by computer cable to a Pentium/ 75 MHZ laptop computer. Both switches were flush with the top of the tapping board. On top of the board were two ten-centimetre vertical posts attached to the side edges of the board with a sliding adjustable reference bar above and across both tapping keys. A typing stand was used to hold the 13 x 20 cm sheets of papers containing tongue twisters.

The O.F. and T.D. varied in each condition as follows. The O.F. varied from 1.00 ounce for the left switch to 12.75 and 14.38 ounces for the right switch, in the Standard, Adjusted and Exaggerated conditions, respectively. For the Adjusted and Exaggerated conditions, subjects were told to disregard moving their right index finger up and down between the reference bar and the right-switch. Following Kee and Cherry's (1990) Standard condition design, the right hand's index finger tapped on the left-switch for the Standard condition in this study.

The travel distance for the left hand varied across the conditions. In the Adjusted condition the T.D. from the bottom of the bar to full depression of the switch was 6 centimetres. Within both of the Standard

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and Exaggerated conditions movement up and down between the reference bar and the left switch were not required.

To vary the O. F., the following procedures were used. Any position on the right-lever moving away from the fulcrum, gradually resulted in a decreased operating force. Conversely, moving along the switch towards the fulcrum increased the operating force of the right-switch. The toughest position on the right-switch to depress was between the fulcrum and the lever hinge, where the lever attaches itself to the switch. A coloured marker was placed on the right-lever to indicate where the subject was to place their index finger for tapping. A green dot in the middle of the right-switch represents the Adjusted position (A), while a red dot, placed between the fulcrum and the lever hinge, distinguished the Exaggerated position (E; see diagram in Appendix C for different positions on micro-switch for each condition).

Discriminating Criterion Between Conditions. The right-switch contained two levels of operating forces pertaining to the Adjusted and Exaggerated conditions. The green dot, indicating the Adjusted condition, had an O.F. of 12.75 ounces, while the Exaggerated condition, indicated by the red dot, had an O.F. of 14.38 ounces. The operating forces for

both of the previously mentioned conditions were chosen to replicate Kee and Cherry's (1991) methods. The left-micro-switch had a consistent O.F. of one ounce. This switch was used by the left-hand in all three conditions. However, in the Adjusted condition, subjects were instructed to touch a reference bar when tapping with their left hand. This was done in order to equalize left and right hand tapping rates (i.e., the left hand had to be slowed slightly). For the other two conditions, subjects were instructed to tap with their left hand in a 'free style' fashion (i.e., tapping without using the reference bar). The right hand tapped freely on the right micro-switch in the Adjusted and Exaggerated conditions, and on the left micro-switch in the Standard condition. The reference bar was not used for the right hand in any condition.

Different levels of T.D.'s exist for each subject's left-hand between all three conditions. The T.D. for the Adjusted condition was 6 centimetres from the bottom of the reference bar to full depression of the left-switch. The Exaggerated and Standard condition have a T.D. of 1 cm starting from the top of the left-switch to full depression of the switch. The reference bar was pre-adjusted to the appropriate height for the Adjusted condition prior to the commencement of the experiment.

In summary, the operating force was different for right hand tapping in all three conditions. The different O.Fs. for the Standard and Adjusted conditions were selected to replicate, as closely as possible, Kee and Cherry's (1991) methodology. The Exaggerated condition did not replicate any other methodology in the literature, since it has never been used before. The operating force for the left hand was similar for all three conditions.

The travel distance for the left hand varied across conditions. The left hand in both the Standard and Exaggerated conditions did not use the reference bar. Whereas the Adjusted condition, for the left hand, did use the reference bar. This was the only condition and hand that used the reference bar. The travel distance for the right hand remained the same across conditions and the reference bar was not needed for this hand in any of the three conditions.

Procedures.

All subjects completed the tasks in the same order. After signing an informed consent form, they filled out a general background questionnaire which was created by Dr. Parlow, and completed the Edinburgh Handedness Inventory (Oldfield, 1971). They then completed

the Wexler's fused word test presented dichotically to both ears. Finally, the dual task tests were: verbal testing alone (i.e. tongue twisters), tapping alone (i.e., baseline), and a combination of both tapping and verbal testing condition (See Appendix B for examples of these test batteries). Each subject completed the latter procedure in one of the three conditions (Standard, Adjusted , or Exaggerated).

General Background Questionnaire. This questionnaire was designed by Parlow (personal communication) and consisted of a variety of questions about personal and familial handedness, medical history and personal history (See Appendix B). The handedness questions assessed the right- or left-hand's preference for 15 common activities. Subjects indicated their right-, left-, or both-hand preferences for each activity by circling the appropriate letter (i.e., L, R, or B). A handedness laterality quotient (L.Q.) was obtained by taking the difference between the calculated right- and left-hand scores divided by the sum of the correct scores. Scores varied between -100 and +100. A high positive score indicates a strong right hand preference for tasks. Conversely, a high negative score indicated a strong left hand preference. Subjects with low scores (i.e., around zero) had no hand preference. Like the Oldfield

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(1971) questionnaire below, any score equal to or greater than half of one standard deviation from the mean was kept to classify right-hand preference and any score equal to or less than one standard deviation from the mean was used to categorize left-hand preference (see further explanation below).

Edinburgh Handedness Inventory. A 12 item questionnaire created by Oldfield (1971), measures hand preferences for typical everyday activities. For each item subjects indicated their hand preference by marking a (+) sign in one of the appropriate columns. A left or right hand preference was indicated by marking a (+) sign in both columns, while a strong hand preference was indicated by marking (++) sign in the appropriate column. A handedness laterality quotient (L.Q.) was obtained by determining the difference between the tallied right- and left-hand scores divided by the aggregate of both scores. Scores varied between -100% to +100%. A high positive score indicated a strong right hand preference for tasks. Conversely, a high negative score indicated a strong left hand preference. Subjects with low scores (i.e., around zero) had no hand preference.

Only 5 of the 12 questions were used to score a subjects hand

preference. These five criterion, taken from Bryden's (1977) factor analysis of this Handedness Inventory, represented the best criterion for determining hand preference. Only subjects with high negative or positive scores were used in the statistical analysis of this study. To differentiate between high positive and negative scores, Bryden's (1977) and Oldfield (1971) suggested that a positive score equivalent to or greater than half of one standard deviation from the mean should be kept to classify right-hand preference. That is, a score above an arbitrary value (X) means the right hand was preferred over the left hand. Conversely, a negative score equal to or less than one standard deviation from the mean should be used to distinguish left-handers. In other words, any score below an optional value (Y) means the left hand was preferred over the right hand.

Dichotic Listening. The Wexler-Halwes' fused rhymed word test (Wexler & Halwes, 1983) was used to assess hemisphere dominance for speech. This test was composed of thirty pairs of monosyllabic rhymed consonant-vowel-consonant (CVC) words presented dichotically in blocked trials. Each pair differed acoustically only on the initial consonant (e.g., deer; beer). The words were matched for high word frequency.

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These stimuli "fuse" into a single auditory image in such a way that subjects typically reported hearing only one word on each trial. Subjects responded by circling the word they hear from among four words printed on an answer sheet. The difference between the number of responses presented to each channel (right or left ear) was divided by the sum of correct responses to assess the subject's dominant hemisphere for language. The laterality quotients varied from -1.00 to +1.00. A positive coefficient indicated left-hemisphere dominance for language.

This investigation used the same criterion suggested by the developers of the dichotic listening test (Wexler & Halwes, 1983; Wexler, Halwes, & Heninger, 1981). From their study they suggested that a score of .11 or higher was significant enough to differ from zero. Therefore, they used -.11 or lower scores to classify left ear dominance and +.11 or higher scores to classify those with right ear dominance.

Verbal Test. Tongue twisters were selected from 'Mother Goose' (Baring-Gould & Baring-Gould, 1962) and from Dr. Seuss' (1965) 'Fox in Sox' book (See appendix B for examples). Although none of the tongue twisters from Dr. Seuss had been used before, the fact that they were tongue twisters (turn to appendix B and try for yourself !) and no specific

list of tongue twisters was recommended in the literature, this study used these tongue twisters as the secondary task. Besides, Hiscock (1982) used traditional tongue twisters (e.g., Peter piper) and his 'gain score' results were similar to my pilot testing results using Dr. Seuss' material (see Secondary Task: Effects on Performance above) . There were six pages of tongue twisters with approximately three twisters per page constructed for the use in the present experiment. Arial font was used and the type size was 14.

Subjects were instructed to read the tongue twisters on the sheet aloud as quickly as possible. A couple practice trials were allowed using the first page of tongue twisters to practice on (See appendix B 'Twister 1' for this practice tongue twister).

Finger-Tapping Task (based on the procedures developed by Kee & Cherry, 1990; McBride, Cherry, Kee & Neale, 1994). Subjects were quasi-randomly assigned to one of three finger-tapping conditions (Standard, Adjusted , or Exaggerated) and completed both tapping blocks (Baseline and Dual task). Each tapping block consists of two ten-second trials per hand with a 30 second break between trials. Determination of which hand and which block each subject received first

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was done by counter-balancing handedness by block across all subjects. Half of the subjects started with their right hand and the other half with their left hand. Quasi-random assignment of half of the subjects to begin with their dominant-hand in half of the block trials (i.e., baseline or dual task) avoided possible systematic order biases between block trial order and hand order.

A demonstration on tapping for each hand was given by the experimenter to the subject, in order to show how tapping should be properly done. Note that regardless of which hand they were going to tap with, they were to place that hand on the board so that their hand and wrist were resting on top of the board. The other hand not used at the time was to rest freely on top of the board without interfering with the tapping hand.

Before tapping began, subjects were instructed to make sure that the top side of their left hand's index finger (i.e., the side with the finger nail) touched the bottom of the preset reference bar which was directly over top of the micro-switches. When the experimenter said "go" they moved their index finger directly down towards the switch below and made the switch 'click'. Once they make the switch 'click' they then

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returned their finger back to the 'ready position'. Finally, they were instructed to perform this tapping procedure over and over again as quickly as possible using their left index finger.

The procedures differed slightly with the right hand's index finger. For the right hand's index finger, subjects were instructed to place their finger on the appropriate coloured dot. When they were told to start, the subject tapped on the switch as quickly as they possible without lifting their finger off the switch. In other words, in all conditions, subjects were told to disregard moving their finger up and down between the reference bar and the switch.

Each subject sat in front of a small wooden box (36 x 24 x 6 cm) and completed a couple of practice trials using the index finger of the left hand on the left-hand side micro-switch. They were allowed to practice tapping on the right-hand micro-switch position with their right hand according to the designated position for the condition to which they were quasi-randomly assigned. For example, a subject quasi-randomly assigned to the Standard condition would place his/her right index finger on the yellow dot which was placed on the far end of the switch (see Appendix C for a diagram of the switch positions).

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Baseline Block. Subjects were instructed to tap as quick as possible while looking directly straight ahead at a (+) sign positioned on the top-middle side of a 13 x 26 cm card. The card sat on a copyholder stand directly behind the tapping board. The approximate distance between the subject and the stand was 70 cm. They were instructed to tap exactly as they had practised. For each block, there were two ten-second trials for each hand and a 30 second break between each trial to avoid onset of musculature fatigue. When the subject was told to start, they began to quickly tap for ten seconds until they are told to stop.

Dual Task. As in the baseline condition, subjects were instructed to tap as quickly as possible. Concurrent with their tapping, they were also instructed to read aloud as many tongue twisters as possible within the allotted 10 second time limit. They were also informed to start a new tongue twister at the beginning of each trial. Before starting, subjects were informed that If they finish a tongue twister before the trial's time limit was completed, then they were to begin the next tongue twister directly beneath. In the event that they finished the last tongue twister on the page before the time limit was up, they were instructed to begin again at the top of the current page. Again, for each block, two ten-second time

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trials for each hand were given with a 30 second break between each trial.

In the remote event that the subject's finger tired during a 10 second tapping trial, they were informed that they had the right to terminate the trial. Inquiry of the subject's condition was constantly monitored between trials. When all trials and blocks were completed, subjects were then debriefed about the experiment.

Assessing Change Scores. In order to assess the impact of interference on tapping, the raw data for each hand in each of the three conditions were transformed to produce a Change score value using the following formula: $X = (B - D) / B \times 100$, where B represented the baseline tapping score for that hand, and D was the dual task raw score for the same hand.

Alterations made to the Baseline Hand Data.

The baseline scores were transformed in two different ways: 1) by an altered Change score method suggested by Kenny, 1979, and 2) using an altered ANCOVA method suggested by Campbell and Boruch, 1975.

The new baseline scores used in the altered Change score analysis were calculated using formula 1 in Appendix D. The baseline

scores were also re-adjusted using formula 2 (found in Appendix D) to make new baseline scores to be used as covariates in the altered ANCOVA method (see Appendix D for description of these formulas).

Criteria For Inclusion into the Analyses.

Two samples were selected for analyses, using different criteria to screen for right-handedness and left hemisphere language dominance. The larger sample (Group A) was selected using a liberal criterion. According to clinical studies (e.g., Bryden, 1982 ; Wada et al, 1960) approximately 95% of those who are right handed are also left hemisphere dominant for language. The first criterion for selecting subjects into group A was that they had to have a right hand preference as indicated by a positive Edinburgh Handedness laterality quotient (i.e, $EDLQ \geq 0$). After the first criterion was satisfied, the second criterion was to select subjects who had a dichotic listening laterality quotient (DICHLQ) of $\geq .17$ or higher). Since the literature does not specify which of the 95% were left hemisphere language dominant, an arbitrary value of $\geq .17$ on the DICHLQ was drawn, after the data were collected, which represented 95% of Group A. The idea was to eliminate 5% of the subjects in Group A who had the most negative dichotic laterality scores

(Wexler & Halwes, 1983).

A second sample (Group B) was also selected using a stricter criterion to identify subjects with left hemisphere speech. A cut off score of $\pm .11$ on dichotic listening test was recommended by Wexler and Hawles (1983) for selecting subjects with left hemisphere speech dominance. Only subjects with an EDLQ score of .60 or greater were included in Group B.

This procedure produced two over-lapping samples, a larger sample (N= 71) called Group A, and a smaller sample (N= 23) called Group B. All of the subjects in Group B were also included in Group A. In Group A, 25 participants completed the Standard condition, 24 the Adjusted condition, and 22 the Exaggerated condition.

In Group B, six participants completed the Standard condition, eight the Adjusted condition, and nine the Exaggerated condition. There were roughly the same proportions of males and females in each of the Groups and Conditions. The findings for Group A were presented first, followed by a comparison of the results for Group B.

Results

Descriptives.

The means and standard deviations for both samples were presented for age, handedness (EDLQ), language dominant hemisphere (DICHLQ), and first language in table 2. The results for both samples are presented below.

Although females were generally older (Sample A: ($M = 272.34$ months, $SD = 65.92$; Sample B: $M = 292.30$, $SD = 106.37$) than males (Sample A: $M = 252.50$ months, $SD = 28.11$; Sample B: $M = 261.80$ months, $SD = 39.26$), the age difference between males and females was not significant, in either sample [Group A: $F(1,69) = 2.39$, $p = .126$; Group B: $F(1,21) = .728$, $p = .400$]. In general, sample B was older (by an average of 6.7 months) and with more right handed and higher DICHLQ scores. English was the first language for 86% of the large sample and 91% in the small sample. From the large sample 14% spoke another first language, as well as English, compared to 9% in the small sample.

Insert Table 1 about here

Baseline Tapping.

The data for each baseline condition were analysed separately

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using ANOVA to determine which hand differences were as expected in each Condition. Hand was entered as a repeated measure.

The data for Group A were analysed first. In the Standard condition, it was found that the right hand tapped faster ($M = 59.80$, $SD = 8.69$) than the left hand ($M = 52.06$, $SD = 5.77$), $F(1,24) = 28.83$, $p < .001$. In the Adjusted condition, the right hand tapping rate ($M = 44.89$, $SD = 6.68$) was not different from that of the left hand's tapping rate ($M = 42.54$, $SD = 4.99$), $F(1,23) = 3.02$, $p = .096$. Finally, in the Exaggerated condition, the left hand ($M = 49.50$, $SD = 5.58$) was faster than the right hand ($M = 34.86$, $SD = 7.89$), $F(1,21) = 47.61$, $p < .001$.

The results for Group B were similar. In the Standard condition the right hand tended to tap faster ($M = 63.58$, $SD = 14.31$) than the left hand ($M = 52.50$, $SD = 4.29$), $F(1,5) = 5.24$, $p = .070$, although this difference was not significant in the small sample. In the Adjusted condition the right hand tapping rate was not different ($M = 44.31$, $SD = 4.20$) from that of the left hand's tapping rate ($M = 47.31$, $SD = 8.71$), $F(1,7) = .90$, $p = .375$. In the Exaggerated condition, the tapping rate for the left hand ($M = 47.66$, $SD = 6.18$) again exceeded that of the right hand ($M = 36.38$, $SD = 8.13$), $F(1,8) = 6.76$, $p = .032$.

Traditional Change Score Analyses.

Having determined that the baseline hand differences were manipulated effectively by the three experimental conditions, the assessment of interference's impact on tapping was determined next. Accordingly, the next step was to calculate the Change scores, using the traditional Change score formula previously outlined.

These scores were then subjected to a 3x2x2 ANOVA to look at the effects of Condition (Standard, Adjusted, Exaggerated), Hand (right vs left), and Gender (male, female). Hand was entered as a repeated measure; Condition and Gender were both between-subjects variables.

No effect of Gender was found, nor did this variable enter into any interactions in the analyses that follow. Since these results were not significant they will not be reported for the remainder of this paper. The main effect of Condition in both samples were also not significant. None of those results were reported for the remainder of this paper.

Figure 1 depicts the Change scores for each hand and Condition for Group A. The interaction of Condition x Hand narrowly missed the standard statistical criterion for significance, $F(2,65) = 3.11$, $p = .051$. A larger sample size would probably be needed to increase the probability

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for detecting a significant interaction. If the Condition x Hand interaction were significant, it would have accounted for only a small proportion ($\eta^2 = 8.4\%$, power = .580) of the variance. The right hand appeared to have a larger Change score value (Standard: $M = 17.52$, $SD = 10.89$), Adjusted: $M = 21.68$, $SD = 12.82$;) than the left hand (Standard: $M = 15.14$, $SD = 9.01$; Adjusted: $M = 17.10$, $SD = 16.44$) in each of the conditions, except for the Exaggerated (Right: $M = 11.63$, $SD = 15.51$; Left: $M = 17.40$, $SD = 14.51$).

The main effect for Hand was also non-significant for group A, $F(2,65) = .27$, $p = .606$. The percentage of interference for the right hand ($M = 17.10$, $SD = 13.55$) did not differ from the percent of interference for the left hand ($M = 16.50$, $SD = 13.45$). This main effect did not account for any of the variance ($\eta^2 = 0.1\%$), but the power was very low (.043).

Insert Fig. 1 about here

When the same analyses were repeated for group B, similar results occurred for the interaction of Hand x Condition, $F(2,17) = .38$, $p = .689$ (see Figure 2). Examination of the power (.095) suggested that the

differences between hands in each of the three conditions was not enough to detect an interaction, if there was an interaction to be detected. Again, examination of these measures suggested that the right hand Change score (Standard: $M = 13.83$, $SD = 5.45$; Adjusted: $M = 28.59$, $SD = 13.76$) was larger than the left hand scores (Standard: $M = 10.98$, $SD = 5.26$; Adjusted: $M = 22.33$, $SD = 15.48$) in all of the Conditions, except for the Exaggerated (Right: $M = 16.31$, $SD = 12.18$; Left: $M = 18.49$, $SD = 17.94$).

The main effect of Hand (Right: $M = 19.94$, $SD = 12.80$; Left: $M = 17.87$, $SD = 14.83$) was also non-significant, $F(1,17) = 1.29$, $p = .212$. The power of this main effect was also small (.247), which made detecting any hand differences, if they truly do exist, difficult.

Insert Fig. 2 about here

Because past neuropsychological dual task research had reported a right hand interference effect using traditional Change scores, speculation about the possible impact of the Exaggerated condition (not used in previous research) was considered. A 2x2 ANOVA was used to

re-analyse the traditional Change score with the Exaggerated condition removed.

A significant Hand effect was revealed by this analysis, $F(1,57)=4.99$, $p=.029$. As expected, greater interference was observed for the right hand ($M=22.22\%$, $SD=13.11\%$) than for the left hand ($M=17.74\%$, $SD=13.07\%$). The Condition by Hand interaction was not significant, $F(1,57)=.49$, $p=.488$. Thus in the absence of the Exaggerated condition, the expected right hand effect emerged.

Altered Change Score Analyses.

In order to control for 'initial hand' differences the baseline scores were altered. This altered baseline value was accomplished by multiplying each baseline score by the pooled baseline standard deviation divided by the pooled dual task standard deviation. The new altered baseline score for each hand was then used to calculate a new Change score value, using the same formula as before.

The effects of Condition, Hand and Gender were again analysed using a $3 \times 2 \times 2$ ANOVA. Figure 4 depicts the interaction of Condition x Hand. Again, this interaction was not significant, $F(2,65)=2.73$, $p=.073$. This effect accounted for a smaller proportion of the variance ($\eta^2=$

7.10%, power= .504), than in the previous analysis.

The Hand effect was significant, $F(1,65)= 69.77$, $p= .001$, when using the altered Change scores. The average right hand score was greater when collapsed across conditions ($M=26.93\%$, $SD= 11.94\%$) than was the left hand ($M= 12.26\%$, $SD= 14.13\%$). This Hand effect accounted for about half the variance ($\eta^2= 51.2\%$, power= 1.00). Apparently, the adjustment affected the pre-existing hand differences in a way that allowed for dramatic improvements in predictability of interference effects between hands.

Insert Fig. 4 about here

The results for Group B were also similar (see Figure 5). The Hand x Condition effect was even smaller, $F(2,17)= .14$, $p=.874$, probably reflecting the smaller sample size (power= .069).

Again, the Hand main effect was significant, $F(1,17)= 41.29$, $p< .001$, and accounted for 70.4% of the variance (power= 1.00). The score for the right hand ($M= 29.14\%$, $SD= 11.36\%$) was higher than for the left hand ($M= 11.84\%$, $SD= 12.26\%$).

Insert Fig. 5 about here

The impact of the Exaggerated condition was also investigated similarly with the other three statistical analyses. When the Exaggerated condition was omitted from the analysis, similar results were obtained. The Altered CSA main effect of Hand was significant, $F(1,45) = 86.74$, $p < .001$. More interference occurred for the right hand ($M = 29.10\%$, $SD = 10.52\%$) than for the left hand ($M = 11.84\%$, $SD = 13.74\%$). The Hand x Condition was not significant, $F(1,45) = .01$, $p = .907$, and the Hand x Condition x Gender interaction was also not significant, $F(1,45) = 1.51$, $p = .225$.

In summary, both traditional and altered Change score analyses produced similar findings with respect to the non-significant Hand x Condition interaction. However, the results differed dramatically with regards to the Hand main effect. The traditional Change score analysis failed to reveal a Hand difference overall, (when the Exaggerated condition was excluded), whereas the altered Change score analysis revealed the right hand effect consistently across conditions as predicted

by the FCS model. Therefore, the altered Change score methodology diminished the impact of the Exaggerated condition.

Traditional ANCOVA Analyses.

The data were analysed using ANCOVA. As before, a 3x2x2 design was employed to look at the effects of Condition (Standard, Adjusted, Exaggerated), Hand (right vs left), and Gender (male, female). However, to replicate Willis and Goodwin (1987), the baseline tapping values for left and right hands were entered into the analysis as separate covariates. The number of Dual task taps in the condition was used as the dependent variable.

The correlation between the dependent variable and the right hand covariate (Group A: $r = .8616$, $p < .001$; Group B: $r = .9150$, $p < .001$) and the left hand (Group A: $r = .7076$, $p < .001$; Group B: $r = .6646$, $p < .001$) were significant for the larger sample and smaller sample, respectively.

The Condition x Hand interaction for group A was again not significant, $F(2,64) = 1.18$, $p = .313$ (see Figure 6). The interaction contributed about 4.5% of the explained variance (power = .319). The explained variance was less than that observed in the previous analyses too.

The main effect of Hand for group A was (Right: $M = 54.79$, $SD = 8.47$; Left: $M = 56.25$, $SD = 7.86$) not significant, $F(1,64) = 2.31$, $p = .133$. The proportion of variance this variable contributed was small ($\eta^2 = 2.80\%$, power = .281). This proportion of variance was larger than in the traditional Change score analysis (0.1%), but was much less than that of the altered Change score analysis (51%).

Insert Fig. 6 about here

Results Group B were comparable to that of Group A (see Figure 7). The Hand x Condition interaction was again not significant, $F(2,16) = .51$, $p = .608$. The proportion of variance that could be explained by this interaction was low ($\eta^2 = 7.7\%$, power = .166). However, the interaction accounted for more variance than in any of the previous analyses.

The main effect of Hand (Right: $M = 55.32$, $SD = 9.65$; Left: $M = 57.32$, $SD = 7.87$) was also not significant, $F(1,16) = 1.83$, $p = .195$. A small proportion of variance was accounted for by the Hand variable ($\eta^2 = 10.3\%$, power = .289). This result was larger than group A's main

effect of Hand, and larger than the effect as revealed by the traditional Change score analysis, but smaller than the altered Change score analysis.

Insert Fig. 7 about here

With the Exaggerated condition removed, the same pattern was confirmed, with a non-significant main effect of Hand, $F(1,45) = .01$, $p = .924$, and no interactions of this variable with other variables were found, $F_s(1,45) \leq 1.67$, $p_s \geq .203$. This analysis revealed that when 'initial hand' differences were statistically controlled, the right hand effect disappears.

Altered ANCOVA Analyses.

An alternative ANCOVA analysis was the last approach to be evaluated. This time, the altered baseline tapping values (Campbell & Boruch, 1960) for each hand were used as the covariates. Different altered baseline scores were made for each of the three conditions. As such, the altered baseline scores were changed by multiplying the condition's simple baseline-dual task correlation by the difference

between the condition's baseline raw score and baseline mean. The product was then added to the condition's baseline mean to create a new adjusted baseline value.

The correlations between the dependent variable and the right hand covariate (Group A: $r = .7089$, $p < .001$; Group B: $r = .8454$, $p < .001$) and left hand covariate (Group A: $r = .7826$, $p < .001$; Group B: $r = .7164$, $p < .001$) were significant for the larger and smaller samples, respectively.

Analysis of Group A scores revealed a significant interaction of Condition x Hand, $F(2,67) = 5.32$, $p = .007$ (see Figure 8), although the proportion of the variance this interaction explained was relatively small ($\eta^2 = 13.7\%$, power = .847). The variance explained by the interaction in this analysis was greater than in the preceding analyses.

The simple Hand effect was evaluated in each condition. In the Standard condition, the right hand ($M = 55.54$, $SD = 8.19$) performed similarly to the left hand ($M = 52.64$, $SD = 7.20$), $F(1,23) = 1.08$, $p = .310$. However, the power to detect a difference between hands in this condition, if there was one to detect, was meagre (.171). In the Adjusted condition, again the right hand ($M = 59.05$, $SD = 8.06$) and left hand ($M = 59.17$, $SD = 7.73$) did not differ, $F(1,22) = 1.87$, $p = .185$. The only

significance simple effect between hands came in the Exaggerated condition, $F(1,20)= 16.83$, $p= .001$. The right hand's tapping rate ($M= 48.28$, $SD= 8.43$) decreased enough to differ from that of the left hand's tapping rate ($M= 58.44$, $SD= 8.67$). The significant interaction reflects the fact that no hand differences were observed in two conditions, but for one condition (Exaggerated) there was a left hand effect.

Insert Fig. 8 about here

The main effect of Hand was also significant, $F(1,66)= 9.20$, $p= .003$. After alterations had been made, the right hand's mean tapping score ($M= 53.57$, $SD= 8.47$) was significantly different from the larger left hand mean ($M= 57.46$, $SD= 7.86$). This effect explained 12.1% of the variance. This was the second largest Hand size observed across the analyses (the analyses of altered Change scores for Group A was the largest).

Neither Hand or the Condition x Hand interaction effect were significant for Group B (see Figure 9). However, the main effect of Hand did approach significance, $F(2,18)= 3.50$, $p= .077$, although the proportion

of variance accounted by this interaction was relatively small ($\eta^2 = 5.8\%$, $\text{power} = .134$).

Insert Fig. 9 about here

When the Altered ANCOVA analysis was re-analyzed, with the Exaggerated condition excluded, there was no main effect of Hand, $F(1,45) = .25$, $p = .619$. The two-way and three-way interactions between Hand, Condition and Gender were also not significant, $F_s(1,45) \leq .58$, $p_s \geq .450$. These results are not in agreement with the previous Altered ANCOVA results, as the hand effect and interactions were significant in that analysis.

In summary, only one of the approaches employed here produced a significant Hand x Condition interaction — the altered ANCOVA. Two approaches, the traditional Change score and traditional ANCOVA analyses, found the main effect of Hand to not be significant. Conversely, the two altered Change score and altered ANCOVA procedures concluded with the Hand main effect being significant.

Secondary Task Analyses.

Three analyses were performed to investigate the effects of tapping on rate of speech output. Since the results from the same analyses in the small sample were similar to the large sample, only the large sample results are presented.

First, a 3x2x2 ANOVA was employed to look at speech as a function of Condition (Standard, Adjusted, Exaggerated), Hand-order (L-R vs R-L) and Block (Block 1 vs Block 2). Block was averaged across trials (first hand vs second hand). Block was entered as a repeated measure and Condition and Hand-order were both between-subject measures.

The Condition x Hand-order interaction was significant, $F(2,65)=3.92$, $p=.025$ (see Figure 10). Examination of the simple effects suggested that the effect of condition was limited to the R-L groups, $F(2,29)=7.52$, $p=.01$. They produced more speech in the Standard condition ($M=40.54$, $SD=12.82$) than in Adjusted ($M=28.02$, $SD=5.64$) and Exaggerated ($M=34.39$, $SD=5.41$) conditions. This anomaly may be due to a by product of speech output variability, when the left hemisphere is activated first, but this finding was not predicted or clearly understood. Speech output did not differ in the L-R groups, $F(2,36)=.209$, $p=.65$. It

appeared that speech output was greatest for the Adjusted condition ($M=35.40$, $SD=10.82$), then the Exaggerated condition ($M=34.37$, $SD=10.17$), and finally for the Standard condition ($M=33.85$, $SD=9.29$).

Insert Fig. 10 about here

The Block effect was not significant, $F(1,65)=.45$, $p=.504$, nor did this variable interact with the other variables. In particular the three-way interaction of Hand-order x Condition x Block was not significant, $F(2,65)=.41$, $p=.663$ (see Figure 11). Thus, the poor tapping performance of subjects in group R-L cannot be accounted for by any change in the division of their attention (i.e., to give more attention to the speech task).

Insert Fig. 11 about here

The main effect of Condition also approached significance, $F(2,65)=2.39$, $p=.099$. Speech output tended to be greater in the Standard condition ($M=36.80$, $SD=10.79$) than in the Adjusted ($M=32.63$, $SD=8.05$) and Exaggerated ($M=34.38$, $SD=7.26$) conditions.

A second analysis was then performed. In this analysis Hand-order and Block were combined so that the effect of tapping Hand (Right vs Left) could be examined. Hand was entered as a repeated measure; Condition was again entered as a between-subjects variable.

No main effects or interactions were significant. The Hand x Condition interaction was not significant, $F(2,68) = .52$, $p = .597$. The main effect of Hand (Right: $M = 34.72$, $SD = 9.81$; Left: $M = 34.28$, $SD = 9.70$) was also not significant, $F(1,68) = .23$, $p = .631$, nor was the the main effect of Condition, $F(2,68) = 2.11$, $p = .129$ (see Figure 12). With respect to the latter effect, examination of the means suggests that , as in the previous analysis, speech output was high in the Standard condition ($M = 37.28$, $SD = 10.59$) than in the Adjusted ($M = 32.09$, $SD = 8.22$) and Exaggerated conditions ($M = 33.98$, $SD = 7.56$).

Insert Fig. 12 about here

A third ANOVA was then used to compare performance in the dual task trials with performance when speaking alone. A 3x2 ANOVA was used to examine the effects of Block (Speaking alone vs Dual task), and

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Condition (Standard, Adjusted, Exaggerated). Block was entered as a repeated measure.

The main effect of Block was significant, $F(1,68) = 75.38$, $p < .001$. Speech output dropped by 19.65%, from an average of 43.11 ($SD = 8.77$) syllables to 34.64 ($SD = 8.95$) under dual task conditions.

The main effect of Condition was not significant, $F(2,68) = .70$, $p = .499$ nor was the two-way interaction of Condition x Block, $F(2,68) = 2.33$, $p = .105$. However, speech output appeared to decline the most when performing a concurrent finger tapping task for the Exaggerated condition (24.40%), followed by the Adjusted condition (23.87%), and finally speech output decline in the Standard condition (19.07%).

Additional Analysis.

An additional analysis was made to compare the ability of the four statistical methods to identify those right-handed subjects with left hemisphere speech dominance. For each dependent measure (and for each subject) the left hand score was subtracted from the right hand score. If the resulting difference score was positive, this was taken as indicating left hemisphere speech dominance. A negative value was taken to be an indicator of right hemisphere language dominance.

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In this right-handed sample, it was expected that 95% - 100% of the participants would have left hemisphere speech. The altered Change score approach came closest to that figure, identified 85.90% in the large sample and 87% in the small sample, as having left hemisphere language dominance (see Table 2). The data were broken down by Condition in Tables 3 - 5. From the Standard condition, the altered Change score approach identified 96% in the large sample and 100% in the small sample as having left hemisphere speech. In the Adjusted condition 92% in the large sample and 88% in the small sample were also identified as left hemisphere language dominant. However in the Exaggerated condition, this analysis only identified 68% in the large sample and 77.8% in the small sample as having left hemisphere language dominance. The small sample size produced larger frequencies of right handers with left hemisphere speech in all the conditions, except for the Adjusted condition.

Insert Tables 2 - 5 about here

Discussion

The primary focus of this experiment was to evaluate the 'initial values' issue. Two different methods were used to evaluate this issue.

One method was to manipulate the initial values using three different mechanical methods (i.e., the three Conditions). The Standard condition replicated the neuropsychological literature, producing a right hand advantage during baseline trials. The Adjusted condition replicated Kee and Cherry's (1990) results, as it eliminated the baseline hand differences. The Exaggerated condition was added to create a right hand disadvantage (a reversed hand advantage).

In the present study, the right hand baseline tapping rate in the Standard condition was significantly greater than that of the left hand, as predicted. The fact that the hand difference was not found for the smaller sample (Group B) was probably a problem of power, since the means showed a similar pattern. In the Adjusted condition, the hand differences were indeed eliminated in both samples. Finally, in the Exaggerated condition, the hand effect was reversed, as expected for both samples. To date, no other neuropsychological dual task literature has used the latter condition.

These mechanical manipulations of the initial values had little effect on dual task interference scores. Of the three conditions, it did appear that the Adjusted condition, in most analyses, produced slightly more right hand interference effects, than the other two methods. This evidence argues against the initial values idea.

The second type of manipulation investigated the initial values by statistical methods. When the Exaggerated condition was included in the analysis, three of the four procedures revealed a right hand effect across conditions (with one exception described below). This included the traditional Change score and two methods which statistically adjusted the baseline values by effectively partialling out trait instability effects (i.e., the altered Change score and altered ANCOVA analyses). The traditional ANCOVA method produced no hand differences. In addition, the traditional Change score did not reveal a Hand effect.

Why would this be? The same one-ounce switch was used in the left hand trials in all three conditions. It was, therefore, not surprising that the Change scores calculated for the left hand were relatively consistent across conditions, averaging around 17%. The right hand, in contrast, was subjected to different operating forces in each of the three conditions

and across two different switches. The amount of interference observed for this hand increased, as expected, from about 18% in the Standard condition to 22% in the Adjusted condition. However, the rate of interference unexpectedly dropped for the right hand in the Exaggerated condition to 12%. This result was not readily explainable. This result may be due to a confound of different forces with the different conditions. No other condition used the same operating force on this switch, making it difficult to compare across switches. Also, these results could not be compared to any other findings in the literature, since this condition has not been used before. However, when the Exaggerated condition was dropped from the analysis, the right hand effect did emerge in agreement with other neuropsychological dual task research.

A second statistical method was the altered Change score procedure recommended by Lacascio and Cordray (1983). This method in effect slightly reduces baseline scores associated with small variability (i.e., left hand scores) and substantially decreases baseline scores associated with large variability (i.e., right hand scores). This adjustment addresses the initial values issue by reducing the baseline hand differences. Not only did this method confirm the right hand effect, it

dramatically increased the percentage of the explained variance from 0.1% to 70%. In fact, more variance due to hand was explained by this analysis than any of the other statistical approaches. The impact of this method seemed to be greatest for the Adjusted condition, although it increased the magnitude of the right hand effect in all three conditions.

When the sample size was reduced and subjects were selected according to a stricter criteria, the effect of this analysis was to account for more variance due to hand (i.e., from 52% to 71%). There was no effect on the interaction with Condition, however. Thus, the altered Change score method appeared to be extremely sensitive to the hand effect, even with the smaller sample size. This was true with and without the Exaggerated condition. Because the sample size for Group B was small ($N=23$) and the large amount of variance accounted for may have been due to chance. This finding needs to be replicated.

A third statistical analysis was recommended by Willis and Goodwin (1987). This used the baseline scores for each hand as separate covariates. They noted that this approach eliminated several problems traditionally associated with Change scores (e.g., power, reliability, unacceptably large measurement error). This method of

analysis effectively eliminated the right hand effect in their study as well as in the present experiment (in all three conditions).

Willis and Goodwin (1987) did not consider the confounding effect of trait instability in their design which inflates the within-subject variability. Because Hand in the traditional ANCOVA design is treated as a within-subjects factor, the fact that variance due to trait instability was not removed from the error term creates a major problem, making it very difficult to get a possible significant Hand effect. The fourth and final statistical analysis employed was the altered ANCOVA method suggested by Campbell and Boruch (1975). This method attempts to take into account the effect of trait instability by removing pre-existing variance that affects the baseline differences between hands. In the present investigation, the altered ANCOVA in effect reduced the right hand baseline scores more than the left hand, possibly due to large variability associated with the right hand. The new altered score was a function of the simple correlation between the baseline and dual task values, multiplied by the difference between the raw baseline score and the mean score and then added again to the mean for that condition. For example, if the right hand in the Adjusted condition had a raw baseline score of 30

and the right hand mean for this condition was 24, and the simple correlation was .80, then the new right hand baseline score would be 28.8 (e.g., $28.8 = .80(30-24) + 24$). This would be a difference of 1.2 points from the original baseline value. When this altered Change score approach was used, the main effect of Hand reappeared, accounting for about 12% of the variance.

The altered ANCOVA procedure also revealed a significant Hand x Condition interaction, but only in the larger sample. It was the only statistical manipulation to do so. Analysis of simple effects suggested that the existence of the right hand effect was greatest in the Exaggerated condition, contrasting sharply with the results of the traditional ANCOVA approach. The evidence from the Exaggerated condition does not support the initial values issue, since the initial hand advantage favoured the left hand and not the right hand, in this condition. Thus, the right hand effect cannot be accounted for by the higher right hand baseline scores. The other three statistical analyses did not find a significant interaction.

So, why was this altered ANCOVA the most sensitive approach to a possible interaction between Hand and Condition ? Since the speech

output Hand x Condition interaction was not significant, nor in the general right hand direction, it can be assumed that the sensitivity of the altered ANCOVA had to be related to condition rather than to localization of speech effects.

The fact that the right hand effect in the traditional ANCOVA Exaggerated condition was small, but became larger when the altered ANCOVA design was used, is of some interest. The reason may possibly be due to the alteration of the baseline scores afforded by the latter approach. Again, the final baseline score was a function of the correlation multiplied by the difference score, added to the baseline mean for that hand averaged across subjects. The critical point is that the larger the difference score becomes, the smaller the new baseline value becomes. Therefore, large right hand variability in the Exaggerated condition (possibly due to the resistance of the switch itself which might possibly magnify the lateralized interference effect) created a big enough difference to make the new baseline value smaller than the original. Conversely, the initial left hand baseline score variability was consistent between conditions (possibly because of the combination of minimal resistance from the switch and some lateralized interference effects)

which resulted in a smaller difference between the original and the altered baseline score. When comparing the hands, the altered left hand baseline score remained close to its original value, while the altered right hand baseline score decreased from its original value.

However, the main effect of Hand and the interaction of Hand x Condition (with the Exaggerated condition removed from the analysis) were found to be non-significant. This would suggest that the above results were influenced by the inclusion of the Exaggerated condition, rather than from the statistical alteration itself. The results for the Standard and Adjusted conditions could be interpreted as support for Willis and Goodwin's (1987) initial value argument, as there was no hand differences in that analysis. With result would also support Willis and Goodwin's (1987) initial value argument. Caution should be used with regards to the use of the altered ANCOVA, until further investigation into the impact of this statistical analysis on the three different conditions can be made.

Another way to investigate the initial values issue was to look at how these statistical and mechanical manipulations affected the initial values as a function of sample size. The most impressive results came

from the smaller sample (Group B) when the altered Change score approach was used. Although there was not a significant Hand x Condition interaction or even a main effect of Condition, the Adjusted condition appeared to produce more right hand interference (i.e., 37.06%) than in the other conditions. The larger sample (Group A) results followed suit, but with a smaller right hand interference index (i.e., 30.97%). The production of larger right hand interference effects in the Adjusted condition goes against the initial values issue. These results suggest that the altered Change score approach was sensitive enough to use even in a small, but carefully selected sample.

The results of the present investigation suggest that initial values were critical in determining the right hand effect. In fact, statistical (but not mechanical) manipulations of baseline scores appeared to have considerable impact on the outcome when the appropriate adjustment was made. Two analyses (traditional ANCOVA and the altered ANCOVA, only when the Exaggerated condition was dropped) seemed to eliminate the right hand effect entirely. Nevertheless, appropriate adjustments (especially with respect to trait instability in the altered CSA approach) revealed that eliminating the right hand advantage for tapping did not

eliminate the right hand effect. That is, the present data seemed to tentatively support the use of the dual-task interference method as a means of establishing the speech locus in the brain.

Finally, a suggestion was made to resolve the 'initial values' issue by changing the design of the experiment from a mixed factorial to a completely randomized design. Instead of using Hand as a repeated measure, half the right handed subjects would be tested with their dominant right hand and the other half with their left hand. This endeavour would require many more subjects.

This suggestion may not be the most convincing way to resolve the 'initial values' issue. Briefly, the 'initial values' issue relates to the idea that differences between the baseline scores and dual task scores for the dominant right hand will be greater than for the left hand, simply because the right hand is the preferred hand that we use to perform almost all everyday tasks (e.g., writing, drawing, using a computer mouse, opening a door, etc). In order to make the left hand equivalent to the right hand, more practice would be needed until performance rates of both hands become approximately equivalent. Practice will influence interference effects by diminishing the difference between baseline and dual task

scores (Springer et al, 1989). For example, according to the FCS theory, performance of novel cognitive and motor stimuli will require a lot of cerebral space. As the novelty wears off (i.e., more practising of the tasks), performance rates become habituated and less cerebral space is required to perform these tasks. Less cerebral space needed for each of the tasks means less interference will occur between motor and cognitive functioning. Without practice, the left hand of right handed subjects would still be at a disadvantage and this would bring the suggestion to use a between-subjects design back full circle to the original initial values argument again.

The present findings may also speak to other issues, secondary to the primary purpose of this paper. The first issue has to do with the effect of sample size on interference and classification of language dominance by hand. A second issue had to do with the influence of the verbal task performance on interference. A third issue relates to the possible attention trade-offs between cognitive and concurrent motor task functioning. Finally, one may ask whether another attention model could better explain the observed right hand effect better than the FCS model.

Right hand interference effects differed in the present study

according to the characteristics of the sample size used to test this effect. The larger sample was a heterogeneous group that may have included right-handed people with either, right-, left- or bilateral-hemisphere language dominance. The smaller sample was more of a homogeneous group that only included strong right-handed people with conservative dichotic listening values indicating left hemisphere language dominance. Although the size of the second sample was considerably smaller, the use of a stricter criteria for selecting subjects (to increase the likelihood that they had left hemisphere speech) in combination with the altered Change score (and to a slightly lesser extent the altered ANCOVA) method resulted in the most dramatic right hand effect. The altered Change score analysis by accounted for 70% of the interference variance associated with the small sample, but only 50% of the variance was associated with the larger sample. Also, using the same analysis, the right hand percentage of Change was about 30% in the small sample, but dropped to 25% in the larger sample right hand. These data suggest that the altered Change score approach can be used even with a small sample size. This would benefit the neuropsychological dual task research where right hand percentage of Change values are usually small (e.g., Kee and

Cherry, 1990, reported a Change score difference of 10% for the right hand and many other studies report smaller Change scores than this), and samples are often small as well.

However, sample size (combined with selection criterion) did not seem to play a role in classifying right handed subjects with left and right hemisphere language dominance. Using the altered Change score analysis for the large sample resulted in the classification of 85% of the right-handed subjects as having left hemisphere speech dominance. Using the same analysis on the smaller sample increased that classification percentage to 87%, a difference of only 2%.

The size of the interference effects in the current investigation was of some interest, since, as previously noted these effects were often much smaller in the literature than those reported here. This may have been due to the use of tongue twisters as a secondary task. More commonly used secondary tasks included rhymed words, reading a paragraph aloud, or solving anagrams, and these tasks may be less cognitively demanding. The traditional Change score approach (with the Exaggerated condition excluded) produced Change scores comparable to those reported by Hellige et al. (1981), who also used tongue twisters.

The attentional requirements of this task are not well understood, however. Perhaps future researchers might wish to explore the effects of different cognitive tasks (which vary in cognitive demand) on hand interference effects.

The third issue was to investigate the importance of attentional trade-off effects between the lateralized motor and cognitive functions. Our interpretations of the Change scores assumed that the subjects (a) divided their attention evenly between the two tasks and (b) similarly in each of the three conditions. But was this assumption correct ?

Analysis of speech output confirmed that performance on the secondary task was reduced by the concurrent tapping task, and we know that the converse was true. The main effect of speaking alone and speaking while concurrently tapping was significant. This suggested that consistently across the conditions, subjects preferred to focus more of their attention on performing motor functions than performing cognitive functions. Further research might explore the degree of attentional requirements needed when performing two concurrent motor and cognitive tasks, by manipulating the subject's attention between task priorities.

The final issue was raised because the single resource attention model, the model the FCS theory is based on, may not be the best model for explaining these results. Support for the functional cerebral space theory was evident for these right handed subjects, but this evidence only partially supported Kinsbourne and Hick's (1978) FCS model. The FCS model is based primarily on a single resource attention model which basically states that attention is a dependent resource shared between hemispheres. This is why the FCS model predicts that when manual and vocal tasks both require the same resources (i.e., left hemisphere in a right-handed sample), there should be more motor impairment in the contralateral hand. The hand difference would therefore be reversed in the left-handed subjects with the right hemisphere speech. To adequately test the FCS model, it would be desirable to compare subjects with left and right hemisphere speech dominance. In the latter group, a left hand interference effect should be observed across conditions (i.e., in the reverse direction of that found in the present study). One could also compare with left-handed subjects with left hemisphere. This would help to differentiate the effects of practice effects related to handedness from laterality of speech within the brain. All of these tests, if true, would

support a single resource model and the FCS theory. A limitation of the present study was that it did not test manual and cognitive functions that required right hemisphere resources.

Based on the neuropsychological dual task literature, one would expect that lateralized interference patterns would be reduced for right hemisphere tasks and left-handed motor functions. The Change scores found in the few studies that have looked at this have been small compared to right hand interference effects (e.g., Green et al, 1994; Cherry & Kee, 1991). The observation of diminished interference effects for the left hand, when compared to the effects of the right hand, reported by others raises questions about the attention model on which the FCS theory was based – a single resource attention model.

Instead, this data may support an attention model that emphasizes independent attention resources within each of the hemispheres (e.g., Friedman & Polson, 1981; Herdman & Friedman, 1985). For example, a multiple resource model was proposed by Friedman and Polson (1981) that assumed that one hemisphere might process information better than the other, but that each hemisphere would use its own resources to perform the entire task. It also assumed that processing of any type of

information would draw from the same resource pool, because the resources of each hemisphere were not discriminative towards any processing type (i.e., cognitive, motor, etc). Therefore, according to this model, tasks that require the right hemisphere resources tasks might process these task differently than tasks that require left hemisphere attention resources. Hence, the diminished left hand interference effects when compared to the larger right hand effects, may reflect the independent attention resources used when processing these tasks.

Conversely, the small left hand effects reported for left handers in the neuropsychological literature may need to be reinterpreted because traditional statistical approaches were used (i.e., like the traditional Change score approach used in this study). A suggestion would be to use a stricter criteria for left handedness and right hemisphere speech and to try the altered Change score analysis because it might produce larger interference effects. Future researchers may wish to investigate this using right and left hemisphere tasks, and comparing left- and right-handed subjects.

In conclusion, the results of the present investigation revealed that, of the three mechanical Conditions used to manipulate initial hand

differences, no one Condition was statistically better at eliciting more interference than another. Regardless of statistical significance, examining the right hand interference effects across Conditions suggested that the Adjusted condition, with its equivalent baseline hand values, appeared to mechanically resolve the 'initial values' issue better than the other two conditions. This condition might also have emerged as the better condition for eliciting greater right hand interference, if the Exaggerated condition were removed from the analyses.

With regard to the statistical analyses, three of the four statistical methods evaluated in the present project revealed a right hand interference effect that supported the predictions of Kinsbourne and Hicks' (1978) FCS model. The strongest statistical evidence for the FCS model appeared to come from two statistical methods, the altered Change score and the altered ANCOVA. Both methods were effective in detecting hand differences. Probably the most sensitive statistical approach was the altered Change score method, for it was able to account for the most variance in only a small sample.

The altered Change score and traditional Change score approaches (at least when the Exaggerated condition was not included in

either analyses) failed to support the claim that differences between hands in a dual task model were results of a 'statistical artifact'. However, the traditional ANCOVA and altered ANCOVA (with the Exaggerated condition excluded from the analysis), did support the 'statistical artifact' notion of Willis and Goodwin (1987). Researchers may wish to examine the function of each statistical analysis on the three different conditions, to gain a better understanding of these methodological and statistical relationships.

Of the four statistical analyses evaluated here, the best method for addressing the initial value issue was probably the altered Change score approach, because it accounted for the most variance and it successfully addressed the initial value problem. This approach appears to be as effective as equating the hands mechanically. Further testing and replication of these methodological and statistical results should be made and caution used when interpreting the various statistical approaches and their relationship to the FCS model.

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Table 1

Means and SDs for both samples by age, EDLQ and DICHLQ.

Variable	<u>N</u>	<u>M</u>	<u>SD</u>
<hr/>			
Group A			
Age	71	263.96	53.93
EDLQ	71	.73	.19
DICHLQ	71	.09	.13
First Language:			
English	71	86%	
French	71	4%	
Other	71	10%	
Group B			
Age	23	282.00	83.11
EDLQ	23	.84	.14
DICHLQ	23	.22	.10
First Language:			
English	23	91%	
French	23	0%	
Other	23	9%	
<hr/>			

Note: Age= in months. EDLQ= Edinburgh Laterality Quotient. DICHLQ = Dichotic Listening Laterality Quotient.

Table 2

Frequencies of Right handers with Left and Right Hemisphere language dominance for each sample and all Conditions Combined.

Statistic	Sample	
	Group A*	Group B**
	f	f
TCS		
Right Hemisphere	33 (46.50%)	10 (43.50%)
Left Hemisphere	38 (53.50%)	13 (56.50%)
ACS		
Right Hemisphere	10 (14.10%)	3 (13.00%)
Left Hemisphere	61 (85.90%)	20 (87.00%)
Traditional ANCOVA		
Right Hemisphere	34 (47.90%)	12 (52.20%)
Left Hemisphere	37 (52.10%)	11 (47.80%)
Altered ANCOVA		
Right Hemisphere	20 (28.20%)	7 (30.40%)
Left Hemisphere	51 (71.80%)	16 (69.60%)

Note: TCS= Traditional Change Score analysis. ACS= Altered Change Score analysis.

* (N = 71).

** (N = 23).

Table 3

Frequencies of Right handers with Left and Right Hemisphere language dominance for both samples in the Standard condition.

Statistic	Sample	
	Group A*	Group B**
	f	f
TCS		
Right Hemisphere	10 (40%)	3 (50%)
Left Hemisphere	15 (60%)	3 (50%)
ACS		
Right Hemisphere	1 (4%)	0 (0%)
Left Hemisphere	24 (96%)	6 (100%)
Traditional ANCOVA		
Right Hemisphere	7 (28%)	2 (33.30%)
Left Hemisphere	18 (72%)	4 (66.70%)
Altered ANCOVA		
Right Hemisphere	7 (28%)	2 (33.30%)
Left Hemisphere	18 (72%)	4 (66.70%)

Note: TCS= Traditional Change Score analysis. ACS= Altered Change Score analysis.

* (N=15).

** (N= 6).

Table 4

Frequencies of Right handers with Left and Right Hemisphere language dominance for both samples in the Adjusted condition.

Statistic	Sample	
	Group A*	Group B**
	f	f
TCS		
Right Hemisphere	9 (37.50%)	2 (25%)
Left Hemisphere	15 (62.50%)	6 (75%)
ACS		
Right Hemisphere	2 (8.30%)	1 (12.50%)
Left Hemisphere	22 (91.70%)	7 (87.50%)
Traditional ANCOVA		
Right Hemisphere	10 (41.70%)	3 (37.50%)
Left Hemisphere	14 (58.30%)	5 (62.50%)
Altered ANCOVA		
Right Hemisphere	6 (25%)	1 (12.50%)
Left Hemisphere	18 (75%)	7 (87.50%)

Note: TCS= Traditional Change Score analysis. ACS= Altered Change Score analysis.

* (N=24).

** (N=8).

Table 5

Frequencies of Right handers with Left and Right Hemisphere language dominance for both samples in the Exaggerated condition.

Statistic	Samples	
	Group A*	Group B**
	f	f
TCS		
Right Hemisphere	14 (63.60%)	5 (55.60%)
Left Hemisphere	8 (36.40%)	4 (44.40%)
ACS		
Right Hemisphere	7 (31.80%)	2 (22.20%)
Left Hemisphere	15 (68.20%)	7 (77.80%)
Traditional ANCOVA		
Right Hemisphere	17 (77.30%)	7 (77.80%)
Left Hemisphere	5 (22.70%)	2 (22.20%)
Altered ANCOVA		
Right Hemisphere	7 (31.80%)	4 (44.40%)
Left Hemisphere	15 (68.20%)	5 (55.60%)

Note: TCS= Traditional Change Score analysis. ACS= Altered Change Score analysis.

* (N=22).

** (N=9).

Figure 1. Traditional Percentage of Change and standard deviations of Hand x Condition in Large sample. The 'T' line on top of each bar represents one standard deviation.

Figure 2. Traditional Percentage of Change and standard deviations of Hand x Condition in small sample. The 'T' line on top of each bar represents one standard deviation.

Figure 3. Altered Percentage of Change and standard deviations of Hand x Condition in Large sample. The 'T' line on top of each bar represents one standard deviation.

Figure 4. Altered Percentage of Change and standard deviations of Hand x Condition in small sample. The 'T' line on top of each bar represents one standard deviation.

Figure 5. Traditional ANCOVA Scores and standard deviations of Hand x Condition for large sample. The 'T' line on top of each bar represents one standard deviation.

Figure 6. Mean Traditional ANCOVA Scores and standard deviations of Hand x Condition for the small sample. The 'T' line on top of each bar represents one standard deviation.

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Figure 7. Mean Altered ANCOVA Scores and standard deviations of Hand X Condition for the large sample. The 'T' line on top of each bar represents one standard deviation.

Figure 8. Mean Altered ANCOVA Scores and standard deviations of Hand x Condition for small sample. The 'T' line on top of each bar represents one standard deviation.

Figure 9. Mean Speech output and standard deviations of Hand-order x Condition in Large sample. The 'T' line on top of each bar represents one standard deviation.

BLOCK 1

BLOCK 2

Figure 10. Mean Speech output and standard deviations for Hand-order x Block x Condition in Large sample. The 'T' line on top of each bar represents one standard deviation.

Figure 11. Mean Speech output and standard deviations for Hand x Condition in Large sample. The 'T' line on top of each bar represents one standard deviation.

Appendix A

Effect Size and Sample Size Formulas

1) Effect Size Formula:

$$\omega^2 = R^2 = SSa / SSa + SSs/a.$$

The effect size (ω^2) is equivalent to R^2 which equalled the Sums of Squares between conditions (SSa) divided by the aggregate of the SSa and the Sums of Squares residuals (SSs/a).

2) Sample size Formula:

$$n' = \theta^2 (1 - \omega^2) / \omega^2$$

The estimated sample size (n') is equal to omega squared (θ^2) multiplied by one minus the effect size (ω^2) and divided by ω^2 .

Appendix B

Informed Consent Form

ASYMMETRICAL INTERFERENCE IN TIME-SHARING TASKS: A HANDEDNESS
STUDY. INFORMED CONSENT FORM.

PLEASE READ THE FOLLOWING CAREFULLY AND SIGN BELOW THAT
YOU ARE AWARE OF YOUR RIGHTS AS A VOLUNTARY PARTICIPANT IN THIS
STUDY.

The purpose of this consent form is to inform you about your rights with respect to participation in this study, and to prepare you to make an informed decision as to whether you want to participate or not.

I understand that this experiment will look at the effects of motor interference in a dual-task situation and how this is affected by the lateralization of language to one hemisphere in the human brain. I understand that I will be asked to do several tasks. These tasks include listening to a tape of words presented dichotically (i.e., to both ears simultaneously), finger tapping, and reading aloud tongue twisters. Sometimes I will be asked to do two things at the same time (e.g., tap and solve anagrams). I will also complete two handedness questionnaires. The whole session will take about 40 minutes.

I understand that performing these tasks does not present any risk to me. I realize that tapping for a period of time may cause some tiredness in my hands and arms. If this happens I can ask to stop and rest at any time.

I understand that all the information I provide will be kept confidential and anonymous.

I understand that my participation is voluntary, and that I may terminate my participation from the experiment at any time for any reason without any penalty being

Appendix B continued

attached.

I understand that if I should have any complaints or concerns about this experiment, I should report them to Dr. S. Parlow, the principle investigator (520-2600, ext. 2691). If I have any ethical questions I should contact Dr. Lise Paquet (Chair of Ethics Committee for the Department of Psychology, ext. 2692) or Dr. B. Jones (Chairman of the Psychology Department, ext. 2648).

Signature of Subject: _____ Date: _____

Signature of Researcher: _____ Date: _____

Appendix B

General Background Information Questionnaire

Name: _____ Date of Birth: _____

Gender: M F Today's Date: _____

Telephone #: _____ Months in School: _____

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

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

1) Write?	L	R	B
2) Draw?	L	R	B
3) Remove the top card of a deck of cards (dealing)?	L	R	B
4) Use a bottle opener?	L	R	B
5) Throw a baseball to hit a target?	L	R	B
6) Use a hammer?	L	R	B
7) Use a toothbrush?	L	R	B
8) Use a screwdriver?	L	R	B

Appendix B continued

9) Use an eraser on paper?	L	R	B
10) Use a tennis racket?	L	R	B
11) Use scissors?	L	R	B
12) Hold a match when striking it?	L	R	B
13) Stir a liquid or semi-solid?	L	R	B
14) Which shoulder do you rest a bat before swinging?	L	R	B
15) With which foot do you kick a ball?	L	R	B

3. Consider the four pictures below. Mark the box under the picture that looks most like the way you hold your hand when writing?

Appendix B (continued)

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

Father = Right-handed? Left-handed? Do not know?

Mother = Right-handed? Left-handed? Do not know?

How many left-handed brothers do you have? _____

How many left-handed sisters do you have? _____

How many right-handed brothers do you have? _____

How many right-handed sisters do you have? _____

Please specify any other left-handed relatives you might have?

(e.g., mother's brother). _____.

5. Learning Disabilities:

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

1) No

2) Yes, in Reading

3) Yes, in Math

4) Yes, in Spelling

5) Yes, in _____

Appendix B continued

5b. Have you ever been identified by a qualified professional as having a learning disability?

1) No

2) Yes, by a School Psychologist

3) Yes, by a Clinical Psychologist outside of the school system

4) Yes, by a Medical Doctor

5) Yes, by _____

6) If you answered yes, at what age? _____

6. Medical History:

6a) Have you ever had a head injury, seizures or other neurological problems?

6b) Any serious injury to fingers, left or right hand or back?

6c) Do you have any hearing problems? (if yes, specify which ear)

Appendix B (continued)

7. Personal History:

7a) What is your first language? _____

7b) Do you speak any other languages fluently? Yes / No

7c) If yes, what are they? _____

7d) Do you play a musical instrument or sing? Yes / No.

7e) If yes, circle the one that you do (sing / play a musical instrument)?

7f) Rate your ability to play a musical instrument or sing and circle your choice below:

None	Novice	Intermediate	Expert
1	2	3	4

7g) Rate your typing ability and circle your choice:

None	Novice	Intermediate	Expert
1	2	3	4

Appendix B

Edinburgh Handedness Questionnaire

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

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

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

	LEFT	RIGHT
1 Writing		
2 Drawing		
3 Throwing		
4 Scissors		
5 Toothbrush		
6 Knife (without fork)		
7 Spoon		
8 Broom (upper hand)		
9 Striking Match (match)		
10 Opening box (lid)		
i Which foot do you prefer to kick with?		
ii Which eye do you use when using only one?		

L.Q.

Leave these spaces blank

DECILE

Appendix B

Dichotic Listening Task Example

The first page is to familiarize you with the words that you will hear throughout this listening test. Please circle each word as you hear it.

The following six pages are the actual test. You will be required to reverse your earphones after completing page 3 and again after completing page 5. Please follow instructions given at the bottom of each page.

EXAMPLE:

1.	gale	bale	pail	tail
2.	pan	tan	can	man
3	page	cage	gage	rage
4.	keg	beg	peg	leg
5.	deer	beer	pier	tear
6.	rage	cage	gage	page
7.	took	cook	rook	book
8.	beer	tear	pier	deer
9.	boy	toy	coy	roy
10.	roy	coy	toy	boy
11.	man	pan	tan	can
12.	pier	tear	deer	beer
13.	den	ken	ten	pen

Appendix B

Twister 1

Practice ... Moses supposes his toeses are roses,

But Moses supposes erroneously;
For nobody's toeses are posies of roses
As Moses supposes his toeses to be.

Robert Rowley rolled a round roll round,
A round roll Robert Rowley rolled round;
Where rolled the round roll Robert Rowley rolled
round?

Peter Piper picked a peck of pickled pepper;
A peck of pickled pepper Peter Piper picked;
If Peter Piper picked a peck of pickled pepper,
Where's the peck of pickled pepper Peter Piper
picked.

How much wood would a woodchuck chuck
If a woodchuck could chuck would?
He would chuck as much wood as a woodchuck
could chuck,
If a woodchuck could chuck wood.

Appendix B continued

Twister 2

Betty Botter bought some butter,
But, she said, the butter's bitter;
If I put it in my batter
It will make my batter bitter,
But a bit of better butter
Will make my batter better.
So she bought a bit of butter
Better than her bitter butter,
And she put it in her batter
And the batter was not bitter.
So 'twas better Betty Botter bought a bit of better
butter.

Fox socks.
Box knox.
Knox in box.
Fox in socks.
Knox on fox in socks in box.
Socks on Knox and Knox in box.
Fox in socks on box on Knox.
Chicks with bricks come.
Chicks with blocks come.

Appendix B continued

Chicks with bricks and blocks and clocks come.

Look, sir. Look, sir.

Mr. Knox, sir.

Let's do tricks with bricks and blocks, sir.

Let's do tricks with chicks and clocks, sir.

First, I'll make a quick trick brick stack.

Then I'll make a quick trick block stack.

You can make a quick trick chick stack.

You can make a quick trick clock stack.

Appendix B continued

Twister 3

Socks on chicks and chicks on fox.

Fox on clocks and bricks and blocks.

Bricks and blocks on Knox on box.

Now we come to ticks and tocks, sir.

Try to say this Mr. Knox, sir...

Clocks on fox tick.

Clocks on Knox tock.

Six sick bricks tick.

Six sick chicks tock.

New socks.

Two socks.

Whose socks?

Sue's socks.

Who sews whose socks?

Sue sews Sue's socks.

Who sees who sew whose new socks, sir?

You see Sue sew Sue's new socks, sir.

Who comes?...

Crow comes.

Slow Joe Crow comes.

Appendix B continued

Who sews crow's clothes?

Sue sews crow's clothes.

Slow Joe Crow sews whose clothes?

Sue's clothes.

Sue sews socks of fox in socks now.

Slow Joe Crow sews Knox in box now.

Sue sews rose on Slow Joe Crow's clothes.

Fox sews hose on Slow Joe Crow's nose.

Appendix B continued

Twister 4

New goo. Blue goo.

Gooley. Gooley.

Blue goo. New goo.

Gluey. Gluey.

Gooley goo for chewy chewing!

That's what that Goo-Goose is doing.

Do you choose to chew goo, too, sir?

If, sir, you, sir, choose to chew, sir,

with the Goo-Goose, chew, sir.

Do, sir.

Bim comes.

Ben comes.

Bim brings Ben broom.

Ben brings Bim broom.

Ben bends Bim's broom.

Bim bends Ben's broom.

Bim's bends.

Ben's bends.

Ben's bent broom breaks.

Bim's bent broom breaks.

Ben's band.

Appendix B continued

Bim's band.

Big bands.

Pig bands.

Bim and Ben lead bands with brooms.

Ben's band bangs and Bim's band booms.

Pig band!

Boom band!

Big band!

Broom band!

Appendix B continued

Twister 5

Luke Luck likes lakes.

Luke's duck likes lakes.

Luke Luck licks lakes.

Luke's duck licks lakes.

Duck takes licks in lakes Luke Luck likes.

Luke Luck takes licks in lakes duck likes.

Through three cheese trees three free fleas flew.

While these fleas flew, freezy breeze blew.

Freezy breeze made these three trees freeze.

Freezy trees made these trees' cheese freeze.

That's what made these three free fleas sneeze.

Hose goes.

Rose grows.

Nose hose goes some.

Crow's rose grows some.

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Appendix B continued

Twister 6

When tweetle beetles fight, it's called a tweetle beetle battle.

And when they battle in a puddle, it's a tweetle beetle puddle battle.

And when tweetle beetles battle with paddles in a puddle, they call it a
tweetle beetle puddle paddle battle.

When beetles battle beetles in a puddle paddle battle and the beetle
battle puddle is a puddle in a bottle they call this a tweetle beetle bottle
puddle paddle battle muddle.

When beetles fight these battles in a bottle with their paddles and the
bottle's on a poodle and the poodle's eating noodles... they call this a
muddle puddle tweetle poodle beetle noodle bottle paddle battle.

When a fox is in the bottle where the tweetle beetles battle with their
paddles in a puddle on a noodle-eating poodle, THIS is what they call a
tweetle beetle noodle poodle bottled paddled muddled duddled fuddled
wuddled fox in socks, sir!

Fox in socks, our game is done, sir.

Thank you for a lot of fun, sir.

Appendix B

DEBRIEFING: The purpose of this study was to investigate hand differences produced by tapping and solving anagrams at the same time. That is, we were interested in how the left-hemisphere of the brain distributes its attention to various tasks being performed simultaneously. In most people, the left-hemisphere controls both language and preferred hand functions. Solving anagrams while concurrently tapping with the preferred hand divides the majority of the left-hemispheres attention to language functions while less attention is provided for the preferred hand functions. This type of attention discrimination within the left-hemisphere causes a significant decrement in the tapping rate of the preferred hand relative to the non-preferred hand. This is called lateralized interference effects. That is why it was harder for the preferred hand to tap while solving anagrams at the same time, than to tap alone without having to solve anagrams.

Most scientists believe that the hand difference effect caused by lateralized interference in the dual-task condition reflects hemispheric specialization of function. However it has recently been argued by Willis and Goodwin (1987) that the origin of lateralized interference in dual-task conditions is a "statistical artifact" stemming from baseline hand differences and therefore cannot be taken as evidence for hemispheric specialization of function. The present study was done to test the hypothesis that lateralized interference is

indeed dependent on hemispheric specialization of function, as popularly believed.

The primary dependent measure in this study was the number of taps associated with dual-task performance relative to the baseline tapping block, with each hand calculated separately. The independent variables were the tapping blocks (baseline and dual-task tapping), hand-order (preferred and nonpreferred hand), gender (male and female), card order (anagrams), and conditions (standard, Adjusted , exaggerated). Discrimination between conditions was determined primarily by increasing the resistance to the preferred hand for each condition. That is, for example, the switch for the standard condition had the least resistance of all three conditions for the preferred hand. While the Adjusted condition switch had more resistance than the standard switch and less resistance than the exaggerated switch. Finally, the exaggerated condition switch had the most resistance of all three conditions for the preferred hand. All subjects participated in only one of the three conditions in which they were tested with both hands in each tapping block. Therefore, each "condition" was a between-subjects variable, while each tapping "block" was a repeated measures variable.

From the present study we are interested in providing further evidence for lateralized interference as a function of handedness and hemispheric specialization and not some "statistical artifact".

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We appreciate your participation in this study today. Without your participation and that of others our research would be seriously hampered. Your time and efforts given today are greatly appreciated. THANK YOU VERY MUCH !

If you have any questions or comments about this study, please feel free to contact Dr. S. Parlow, the principal investigator (520-2600, ext. 2691). If you have any ethical concerns about this research then please contact Dr. Paquet (Chair of Ethics committee for the Department of Psychology, 520-2600, ext.2692) or Dr. W. Jones (Chairperson for the Department of Psychology, 520-2600, ext. 2648).

Appendix C

Diagram of Tapping Apparatus and Switch Condition Positions

Appendix D

Formulas used to change the baseline scores for the Change score and ANCOVA approaches. The formulas below were used to convert each hand's baseline score, separately. The correlations for each hand by condition are included below.

Altered Change score:

$$(SD_{\text{baseline}} / SD_{\text{dual-task}}) X_{\text{baseline}} = \text{New baseline score.}$$

SD_{baseline} is the hand's baseline standard deviation and $SD_{\text{dual-task}}$ is the hand's dual task standard deviation value. X_{baseline} is the hand's original baseline score.

Altered ANCOVA:

$$r_{ij}(X_{ij} - \bar{X}_j) + \bar{X}_j = \text{New baseline hand score.}$$

r_{ij} is the simple correlation (for whichever condition the subject participated in) between the hand's baseline and dual task tapping rates. X_{ij} is the raw baseline hand score for the particular condition participated in. $\bar{X}_j$ is the mean for the hand and condition participated in.

Appendix D continued

Correlation for each Hand x Condition and sample.

Group A:	Left hand	Right hand
Standard:	.8172 ***	.5802 **
Adjusted:	.4751 *	.7149 ***
Exaggerated:	.5541 **	.7405 ***
Group B:	Left hand	Right hand
Standard:	.9007 *	.9662 **
Adjusted:	.7194 *	.8437 **
Exaggerated:	.3230	.7836 *

* $p < .05$. ** $p < .01$. *** $p < .001$.