Laterality effects in multilinguals during speech production under the concurrent task paradigm: Another test of the age of acquisition hypothesis

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Abstract

The object of the present study was to test the hypothesis that age of acquisition is a significant contributor to laterality effects under a concurrent verbal-manual task condition, but with a substantially larger sample (n = 102) than has been usual in such research. After reviewing the relevant literature and examining several serious analytical and methodological issues that have been raised, the results of an experiment involving three groups of subjects (native speakers, early and late non-native speakers) are presented. Significant differences in laterality effects were uncovered between the native and late non-native groups, thus producing evidence suggestive of increased right hemisphere activation during speech production in a late-acquired second language.

1. Introduction

In 1863, the celebrated French neurologist Paul Broca, commenting on the basis of eight post-mortem examinations of subjects who had suffered from speech loss, noted that all eight of the cases involved lesions to the third frontal convolution of the left cerebral hemisphere (Brown 1972). Since then, it has become well established that the left hemisphere (LH) is dominant for language in approximately 97% of the population, and that of the remaining 3%, most are left handed (Obler and Gjerlow 1999). At the same time, during the last twenty years an increasing appreciation has developed for the role of the right hemisphere (RH), not only in various aspects of nonlinguistic processing ranging from visuospatial recognition to affective-emotive functions, but also in the full expression of linguistic competence (Code 1997; Van Lancker 1997). For instance, in recent studies, the right hemisphere has been found to be involved in the perception of speech sounds such as voiced consonants (Simos, Molfese, and Brenden 1997), communicative pragmatics (Brownell et al. 1997), and word recognition (Iacoboni and Zaidel 1996). Beeman and
Chiarello (1998: 388) may thus be stating an emerging consensus when they write that “clearly the LH is superior to the RH at most language tasks. But just as clearly, both hemispheres are engaged in comprehending language, in uniquely different ways”. Additionally, the debate concerning the cortical representation of language has often been linked to another issue, that of the existence of a specific developmental or “critical” period for the acquisition of language.

2. First and second language acquisition, hemispheric lateralization, and the critical period

2.1. First language acquisition, hemispheric lateralization, and the critical period

The notion of an optimal period for language acquisition also has roots in 19th century France with the famous case of “Victor, the Wild Boy” who was found in the woods of Aveyron in 1799, brought to Paris in 1800, and turned over to the physician Jean Itard for rehabilitation. Victor appeared to be approximately twelve years old at the time of his discovery and had no language other than inarticulate sounds. While a measure of success was achieved with regard to various social and cognitive aspects of his rehabilitation, Itard’s attempts at promoting Victor’s linguistic development were unsuccessful. This failure led Itard to offer, in effect, an inchoate formulation of the critical period hypothesis, when he commented that of all the aspects of early child development, the most astonishing is the ability of children to acquire speech, an ability which is available only during early childhood (Itard [1807] 1964).

A century and a half later, Lenneberg (1967) formulated his own well-known proposal for a biologically based critical period for the acquisition of a first language, and suggested the following developmental scheme. During the first two years of life, the brain experiences a period of rapid growth and is in a state of organizational immaturity; cerebral dominance is not yet established and, at the beginning of language acquisition, both hemispheres may be equally involved. There follows a phase of slower maturation and, by about age fourteen, the adult steady-state is attained with cerebral lateralization of function irreversibly established. In this view, then, the start of the critical period is linked to an initial state of equipotentiality of the cerebral hemispheres for supporting language functions, and its ending at puberty to a termination of organizational plasticity following the gradual lateralization of language functions to the left hemisphere. According to this view, first language acquisition after puberty, to the extent that such a phenomenon could occur at all, would involve activation of neurological processes other than those which underlie normal first language acquisition. The well-known case of Genie, a modern day “wild child” who was discovered at the age of thirteen and a half and who had no
language, illustrates this hypothesis. After four years of intensive rehabilitation, her language development was still quite limited (though clearly superior to Victor’s); more importantly, her language exhibited characteristics strikingly different from those of normal children, including a severe lack of grammatical competence and several indications of predominant right hemisphere involvement in her language acquisition process (Curtiss 1977).

Lenneberg’s (1967) concept of initial hemispheric equipotentiality followed by gradual lateralization fell into some disfavor in subsequent years, as evidence was uncovered to show that the left hemisphere is specialized at birth for speech and language functions. For instance, Krashen (1973) reviewed earlier data including Basser (1962) and concluded that lateralization is complete well before puberty. Early left hemisphere specialization was also indicated by studies such as Molfeze, Freeman, and Palerom (1975) and Ingram (1975) who demonstrated a right ear superiority for verbal stimuli in infants as young as one year, and Bertoncini et al. (1989) who showed that neonates respond significantly more to changes in consonant-vowel syllables (/ba/, /da/, /pa/) presented to the right ear than to the left ear. At the same time, however, neurological case studies continued to provide evidence for hemispheric equipotentiality. For example, in a longitudinal survey of nine children with unilateral antepartum or perinatal brain injury to either hemisphere, Feldman et al. (1992) observed normal rates of linguistic progress after initial delays in the majority of cases, and concluded that both hemispheres may play critical roles in the earliest stages of language acquisition. Vargha-Kadhem et al. (1997) reported on a case of onset of speech in a nine-year-old boy after left hemispherectomy, while Hertz-Pannier et al. (2002) similarly reported on a case of rapid recovery of receptive language but slower recovery of expressive language following left hemispherectomy at age nine years, thus documenting two remarkable cases of right hemisphere language acquisition in late childhood.

In an examination of similar, though earlier, clinical findings, Satz, Strauss, and Whitaker (1990) argued that the term “hemispheric equipotentiality” can be taken as referring only to the capacity of areas of the right hemisphere to carry out functions which are lost due to the unilateral destruction of areas of the left hemisphere, without denying the pre-existence of functional bias favoring left hemisphere specialization for linguistic functions. With respect to progressive lateralization, Satz, Strauss and Whitaker (1990) rejected Lenneberg’s (1967) suggestion that language functions are initially represented in both hemispheres, with the right hemisphere basis for these functions shrinking over time. Instead, they endorsed a proposal by Luria (1973) that lateralization results from the transfer of functions from primary cortical areas to secondary and tertiary areas which reach maturation only in late childhood. At any rate, Satz, Strauss, and Whitaker (1990) concluded that the notions of initial equipotentiality and progressive lateralization which, as previously noted,
had fallen into some disfavor, could in fact be incorporated within currently available neurodevelopmental data. In a comprehensive discussion of neurolinguistic development, Locke (1997: 301) took an even stronger position, arguing that the relevant neuroanatomical facts support “developmental neurolinguistic gradualism” and that there is little reason to suppose that hemispheric priorities are determined in the first few months or even several years of life.

2.2. *Second language acquisition, hemispheric lateralization, and the sensitive period*

If the debate concerning the cortical representation of native languages has been vigorous, then the one regarding the cortical representation of second languages and the extent to which the cerebral organization of the bilingual brain might differ from that of the unilingual brain has been even more contentious. A central question has been the extent to which age of exposure might affect the way language is represented in the brain, a notion which clearly derives from the critical period hypothesis for first language acquisition. It is important to note, however, that while the limitation on first language acquisition is seen as near-absolute under the critical period hypothesis, the limitation upon second language acquisition must necessarily be of a more limited nature, given the evident ability of many adults to attain very high levels of proficiency in non-native languages. Therefore, some researchers have preferred phrases such as “sensitive period” (Oyama 1976; Patkowski 1980, 1990) or “maturational constraints” (Long 1990) in discussing limitations on second language acquisition, though others have stayed with the term “critical period” (DeKeyser 2000; Johnson and Newport 1989; Scovel 1988). What all seem to share is the notion of a period of heightened plasticity followed by reduced plasticity in later life, and the consequent implication that second languages acquired after puberty are qualitatively different from those acquired earlier (Scovel 1969). Simply put, second languages are best learned during childhood.

Several researchers have proposed that second languages acquired early in life may be mediated primarily by the left hemisphere but that right hemisphere participation might increase for second languages learned later in life (Albert and Obler 1978; Galloway 1982; Galloway and Scarcella 1982; Vaid 1983). In a recent statement of this position, Newport, Bavelier, and Neville (2001: 484) assert that “neural organization for late-learned languages tends to be less lateralized and displays a high degree of variability from individual to individual”. Current findings, the authors conclude, “provide fairly strong evidence for a critical or sensitive period in acquiring the phonological and grammatical patterns of the language and in organizing the neural mechanisms for handling these structures in a proficient way” (Newport, Bavelier, and Neville 2001: 485). Other variables besides age of acquisition have also been thought to in-
fluences the cerebral representation of second languages, including manner of acquisition (formal versus informal), and level of second language proficiency (Obler et al. 1982). However, the theoretical basis for the suggested left hemisphere mediation of early second languages and increased right hemisphere participation for late second languages clearly derives from Lenneberg’s (1967) carefully constructed critical period hypothesis, a hypothesis about neurologically based developmental constraints upon first language acquisition under conditions of prolonged naturalistic or informal exposure. Under this model, then, the key research variable is age at acquisition, while other factors such as mode of exposure or proficiency in the second language function more as control than as independent variables.

Such notions of differences in hemispheric asymmetry between bilinguals and monolinguals have been vigorously opposed by Paradis (1990, 1995, 1998a, 1998b, 2000) who has raised theoretical issues, drawn upon clinical evidence, and questioned the validity of experimental approaches. Paradis’s fundamental contention is that bilinguals differ neither neuroanatomically nor neurophysiologically from monolinguals; the organization of the neural substrate is not modified in the bilingual brain, not even for second languages acquired late in life. “Enough, already!” Paradis (1990) has exclaimed in exasperation at proposals concerning the differential lateralization of bilinguals. Yet, he has also proposed that bilingual speakers may make differential use of the same cerebral mechanisms that are available to monolingual speakers and may compensate for gaps in their implicit linguistic competence by relying on right hemisphere based pragmatic aspects when using their weaker language. These matters will be taken up again later. At this point, however, this paper turns to an examination of experimental investigations of lateralization of the bilingual brain.

3. Experimental approaches to testing laterality

3.1. Overview

Experimental investigations into the extent to which there might be greater involvement of the right hemisphere in second languages, particularly in cases involving later acquisition, have followed several research paradigms, though two overall approaches can be usefully distinguished. The first is based on the use of behavioral indices derived from activities such as dichotic listening, tachistoscopic presentation, and concurrent manual-verbal tasks. The second, which has gained a great deal of impetus with recent technological advances, involves neuroimaging, and will be considered in the discussion section at the end of this paper. With respect to the first approach, it is widely perceived that it has yielded variable and controversial results. On the one hand, several studies have claimed to demonstrate differential hemispheric processing for second
languages; on the other hand, several other studies have uncovered opposing evidence, or no evidence at all. A review of selected studies spanning three decades can serve to illustrate this situation. First, a brief survey of dichotic and tachistoscopic studies is offered; this will principally serve to illustrate the frequently remarked upon lack of agreement across studies. Then, a lengthier examination of research based upon the concurrent task paradigm, which the present study follows, is presented. Certain analytical and methodological considerations will be taken into account in an attempt to construct a more cogent view of the research findings and to warrant the method employed in the present study.

As is well known, the dichotic technique involves the simultaneous presentation to both ears of auditory stimuli, in order to evaluate lateralization of function, and is thus limited to investigations of the receptive processing of auditory language stimuli. The technique is made possible by the fact that the right ear has stronger connections to the left hemisphere than to the right, and vice-versa for the left ear. Several dichotic listening studies have found no differences in lateral dominance between first and second languages. A representative sample would include Gordon (1980) who investigated adult English-Hebrew bilinguals, Galloway and Scarcella (1982) who tested adult monolinguals and bilingual learners in the initial stages of acquiring English, Soares (1982) who studied adult male Portuguese-English bilinguals, and Morton et al. (1998) who examined monolingual and bilingual undergraduates. On the other hand, Vocate (1984) compared bilingual Native American Crow and monolingual Anglo elementary school children and concluded that bilinguals are less lateralized for language than monolinguals. Albanese (1985) studied English-French bilinguals, and found that fluent bilinguals showed less of a left hemisphere advantage than their nonfluent counterparts. Fabbro, Gran, and Gran (1991) assessed female interpretation students and professional interpreters with over ten years of experience on tasks involving the recognition of semantic and syntactic errors. The results suggested a lesser degree of hemispheric asymmetry of linguistic functions in fluent bilinguals and polyglots than in monolingual controls. Ke (1992) conducted dichotic listening tasks with adult bilingual English-Chinese speakers and monolingual English speakers; results revealed a significant left hemisphere advantage for monolingual subjects, but not for bilingual subjects, suggesting increased interhemispheric processing with the acquisition of a second language.

A comparable situation prevails with respect to studies using tachistoscopic presentation, a technique which involves extremely brief presentations of visual stimuli to the right and left visual fields, making it possible to evaluate lateralization of function in a manner similar to that employed in dichotic studies. For example, Walters and Zatorre (1978) tested bilingual college students on word pairs in both languages. Results showed a consistent right visual field ad-
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vantage for word identification in both languages but uncovered no evidence of differential hemispheric effects for each language. On the other hand, Shanon (1982) conducted experiments involving both unilateral and bilateral presentation of English and Hebrew words to three groups of subjects (Israelis with a good knowledge of English, Americans with a good knowledge of Hebrew, and full bilinguals) and found not only a generalized right visual field advantage for all subjects in both languages, but also a lesser degree of lateralization for second languages compared to first languages. Similarly, Sewell and Panou (1983) tested the visual half-field performance on verbal and spatial tasks of late bilingual and monolingual subjects. Results showed a significant difference between first and second languages on an index of laterality, with the former yielding a higher score, leading the researchers to conclude that the bilingual groups showed a reduced laterality for their second languages. Wuillemin, Richardson, and Lynch (1994) tested the visual half-field performance of multilingual Papua New Guinean university students and found evidence of increased right hemisphere involvement in second language processing for older learners. However, Workman et al. (2000), conducted a study involving two separate experiments, with English monolingual and English/Welsh bilingual subjects in each, and found no evidence for greater right hemisphere involvement in processing a second language. In fact, the results showed a greater left hemisphere advantage for bilinguals than for monolinguals.

3.2. The concurrent task paradigm: Methodological considerations

A third behavioral measure of lateralization which has been frequently employed involves the use of concurrent verbal and manual tasks. There are consistent research findings that, in right-handed subjects, such concurrent tasks interfere more with right-handed than with left-handed finger tapping performance (Hiscock and Inch 1995; Van Hoof and Van Strien 1997). This approach, also referred to as the time-sharing paradigm, was developed by Kinsbourne and Cook (1971) who ascribed the asymmetric effects to the role of the left hemisphere in controlling both speech and right hand movement. Under the procedure, subjects will typically be asked to say words or sentences aloud (either reading a text or repeating a given phrase or sentence) while simultaneously tapping the index finger as fast as possible. Rates of finger tapping during concurrent tasks are compared to baseline measures to provide evidence for functional lateralization. According to Kinsbourne and Hiscock (1983), the greatest asset of the concurrent task paradigm is that, unlike tachistoscopic presentation and dichotic listening, the time-sharing technique makes it possible to investigate a vast range of cognitive and linguistic tasks, including tasks involving phrase-level and sentence-level production. More recently, in a review of behavioral laterality methods including the dual task approach, Hiscock and
Kinsbourne (1995: 250) did recognize several shortcomings such as “mediocre reliability and a vulnerability to ‘extraneous’ factors” but argued that despite the increasingly prominent role of functional brain imaging and other biomedical technologies, the behavioral methods remain useful, especially if used in conjunction with the other methods to construct a network of convergent factors.

Other researchers have taken a more skeptical view of the time-sharing paradigm. For example, Simon and Sussman (1987) proposed that dual task interference effects reflect manual dominance rather than hemispheric speech dominance; Sussman (1989) questioned the statistical procedures followed in analyzing time-sharing data; and, as previously mentioned, Paradis (see 1990 and 1995 in particular) raised strong objections to the use of all behavioral techniques (visual half-field, dichotic listening and concurrent tapping) in the investigation of language lateralization in bilinguals, questioning both their validity and the reliability of their results. Despite Paradis’s (1995: 174) reference to the “low or nonexistent test-retest reliability” of behavioral indices of laterality, at least two studies with adolescent or adult subjects (Clark, Guitar, and Hoffman 1985; Green 1986) have found test-retest correlations ranging from .42 to .77. While such correlations may indeed be considered mediocre, they certainly rise above the level of nonexistence. On the issue of validity, Paradis (1995) has argued that laterality scores revealed by behavioral measures do not agree with one another and do not correlate with clinical and neuropsychological evidence. Yet, in a recent review of studies investigating auditory asymmetries for speech perception in both normal and brain damaged individuals which utilized three different methodologies (dichotic listening, electrophysiological investigation and lesion studies), Simos, Molfese, and Brenden (1997: 143) did uncover converging evidence: “certain pieces of evidence from brain damaged patients seem to agree with electrophysiological data from our laboratory and others. They are also in accordance with dichotic listening findings indicating greater RH capacity in perceiving the voicing dimension”. O’Leary et al. (1996) found that a right ear advantage for dichotically presented language stimuli corresponded to increased blood flow to the left hemisphere as revealed by positron emission tomography. In a similar vein, Coney (2002) used tachistoscopic presentation to demonstrate behavioral correlates of neuroanatomical differences occasioned by phonological encoding which had been established by an earlier neuroimaging study.

Returning more specifically to the concurrent task paradigm, it is undeniable that the disparate nature of the findings yielded by time-sharing studies does initially give as much pause as the results from tachistoscopic and dichotic studies. However, when issues of sampling, methodology, and analysis are taken into account, it becomes possible to construct a more orderly view. In his comprehensive critique of behavioral laterality research, Zatorre (1989)
presented a lengthy list of potentially confounding factors. Two of these, subject selection and task-related variables, are of particular relevance to the current discussion. Given the previously discussed linkage of the critical period hypothesis to the issue of potential differences in hemispheric processing of second languages, it is particularly important to employ appropriate operational definitions of the terms “early” and “late” acquisition. Since puberty is the most consistently cited end point of the critical period, samples selected to represent “early” acquisition should consist of subjects who clearly have had the opportunity not only to begin but also to complete their second language acquisition during childhood, while subjects selected to represent “late” acquisition ought to have indisputably begun their acquisition after puberty, well into their late teens at the earliest.

Additionally, since the critical period hypothesis specifically applies to language acquisition under sustained conditions of naturalistic or informal exposure, the language histories of subjects must present the relevant characteristics. In particular, it is important to recognize that “bilinguals” whose L2 acquisition is limited to school learning or who have spent extremely limited periods of time living in the L2 environment are not appropriate subjects for studies designed to test the critical period hypothesis. As will be seen below, such conditions do not always prevail in the research. The issue of task-related variables has already been touched upon with the reference to Kinsbourne and Hiscock’s (1983) assertion that the greatest asset of the time-sharing method is its capacity to assess lateralization vis-à-vis production, a characteristic also remarked upon by Zatorre (1989). Indeed, since speech is held to be the most lateralized of language functions (Coney 2002), this characteristic of the concurrent task procedure would appear to represent a significant advantage.

An additional issue, one which is not considered by Zatorre, is that of statistical power. However, as will be seen, sample size and hence statistical power do vary widely in the concurrent task research literature. Even though this issue involves “the least familiar of the concepts surrounding statistical inference among practicing behavior scientists” (Cohen 1977: 10), it is one which merits some discussion. As is well known, the alpha level, or level of significance, which is invariably reported in statistical research refers to the probability of committing a type I error by rejecting the null hypothesis (Ho) when it is in fact true. Power analysis complements significance testing by examining the probability that a statistical test will in fact reject a false null hypothesis. Three key parameters in power analysis are the significance criterion, the size of the experimental sample, and the effect size (ES) or the degree to which the phenomenon is present in the population. Just as significance is generally selected from three levels established by convention (.05, .01, and .001), one may resort to the criteria set for effect size by Cohen who defines “small,” “medium” and “large” effects for a variety of statistical tests. Thus, for any given statistical
test at a given level of significance and with a given sample size, the power of the procedure can be assessed against various effect size levels. As should be intuitively evident, a smaller sample size, other things being equal, leads to a lower power of the test and a lessened probability that any effects will reach statistical significance.

3.3. The concurrent task paradigm: Review of the second language research

A review of several widely cited dual task studies on the differential lateralization of first and second languages is now presented, with consideration of the various issues outlined in the preceding discussion. In an early study, Hynd, Teeter, and Stewart (1980) compared 14 bilingual Navajo and 14 monolingual Anglo adult subjects, using both concurrent and dichotic listening tasks. The concurrent task required verbalization of the words “dog–cat–bird–snake” in English or in Navajo. Findings provided no evidence for increased lateralization of second language functions to the right hemisphere. However, the age at acquisition of English as a second language of the bilingual Navajo speakers was not given, a considerable omission; if the bilingual group in fact underwent early acquisition, these findings would not be in the least unexpected. Furthermore, even in the absence of this consideration, the power of a $2 \times 2$ ANOVA at $\alpha = .05$ with a sample size of 32 is a modest .26 against a medium effect size and .57 against a large effect size (Cohen 1977: 311, Table 8.3.12). In other words, a medium effect would have roughly only one chance in four of being detected, and even a large effect would face just slightly better than even odds.

In contrast, Sussman, Franklin, and Simon (1982) compared the performance of 40 male bilinguals from varying language backgrounds and 40 male English-speaking monolinguals on three concurrent tasks involving reading aloud, describing a picture, and reciting automatisms (e.g., the months of the year). Only right hand tapping rates were disrupted for monolinguals during concurrent tasks, indicating left hemisphere dominance, whereas bilingual laterality patterns were a function of the language being used (first versus second language) and the age at second language acquisition with late bilinguals (mean age of L2 acquisition = 16.3 years) demonstrating greater right hemisphere participation in their second language. On the other hand, Soares (1984) compared 16 late Portuguese-English bilingual adult males and 16 monolingual English adult males on several concurrent tasks involving talking, reciting automatisms, reading aloud, reading silently, and thinking, and reported no lateralization differences across the bilinguals’ two languages, or between bilinguals and monolinguals. Nevertheless, the data presented by the author show a considerably greater reduction in finger tapping for the left hand for bilingual subjects while performing concurrent tasks in their second language, as
compared to doing so in their first language. Unfortunately actual percentages are not given directly but are presented only in bar charts. Thus, reading from Soares’ Figure 2 (1984: 94), right hand tapping appears to decrease by approximately 9 % for L2 and 7 % for L1, while left hand tapping appears to decrease by approximately 5 % for L2 but only 1.5 % for L1. Although it is true that the analyses of variance on these data yielded no statistically significant effects, it is equally true that the sample size involved was too small to allow anything but very large effects to be uncovered by the ANOVA procedure. Indeed, the power of an $F$ test of $2 \times 2 \times 5$ (group by hand by task) interaction effects with a sample size of 32 at alpha = .05 is only .16 against a medium effect size and. 39 against a large effect size (Cohen 1977: 317, Table 8.3.15).

Green (1986) investigated four groups of 24 English speaking adult male subjects. Two of the groups were English speakers at two levels of Spanish proficiency (beginning and low intermediate), the third group was described as consisting of English dominant adolescent bilinguals, and the fourth consisted of English monolinguals. The tasks involved object naming and a picture description. A central purpose of the study was to investigate patterns of laterality in subjects who differed in levels of second language proficiency rather than in age of L2 acquisition. There were, however, findings of relevance to the age issue which showed laterality patterns in adolescent bilinguals to be significantly different from those of monolinguals. The Hall and Lambert (1988) study involved 48 male teenage subjects with a mean age of approximately sixteen years. Three groups of 16 Anglophone students were compared: early French immersion students, late immersion students, and students with limited French instruction. Concurrent tapping/verbal tasks involving reading aloud and object naming were carried out in French and English for the two immersion groups, but only in English for the nonimmersion group, and no significant group differences were uncovered in tapping rates during dual tasks in either language. However, the late immersion subjects had in fact received daily lessons in French as a second language from kindergarten through the 6th grade, followed by 80 % immersion in the 7th and 8th grades and 50 % immersion in the 9th to 11th grades. Thus, it could be argued that this group had in fact received substantial early exposure and did not represent a clear-cut case of “late” acquisition; under such an interpretation, the results would not appear surprising.

Hoosain and Shiu (1989) used both a concurrent task (simultaneous finger-tapping and backward counting) and a tachistoscopic bilateral presentation task with 30 male and female Hong Kong undergraduates (mean age = 20.4 years) who had learned English for more than twelve years and who had used it as a means of instruction for more than six years. The results provided no evidence of differences in lateralization patterns for the two languages. However, whereas all the other concurrent studies discussed here specifically discussed
their procedures for counterbalancing task order. Hoosain and Shiu (1989) did not reveal whether or not task order and practice effects were controlled for in their research. As Kinsbourne and Hiscock (1983) noted, dual task performance improves with practice and several studies, including the present one have uncovered substantial practice effects (see Section 5). Thus, failure to counterbalance task order would represent a severe methodological limitation.

Finally, Furtado and Webster (1991) used two concurrent tasks, which involved reading as accurately as possible and translation, to examine four groups of 16 subjects each: early bilinguals who had developed English/French bilingualism before six years of age; late bilinguals who were monolingual French speakers for at least the first six years of life and who subsequently acquired English; late bilinguals who were monolingual English speakers for the first six years of life and who subsequently acquired French; and monolingual English speakers. Mean ages for L2 acquisition are not given for the late bilingual groups although second language learning is stated to have “almost invariably occurred during or after adolescence” (Furtado and Webster 1991: 450). Subjects were asked to rate their proficiency in various linguistic skills in French and English using scales ranging from 0 to 7. Interestingly the self-ratings in both languages were quite high for all the subjects, including the late bilinguals, falling slightly below 6 in only two of 28 reported mean group scores (Furtado and Webster 1991: 457, Table 5). The results provided no support for the notion of differential lateralization of second languages acquired at different ages but, oddly, did reveal that all the bilingual subjects showed lateralized interference effects when reading in English and translating into English, and no such effects when reading in French or translating into French. In contrast with the Soares (1984) study, where an examination of the data presented in tabular form left room for speculation that a larger sample size might have resulted in significant lateralization effects resulting from age of L2 acquisition, the tabular data presented by Furtado and Webster (1991) appear to present no such possibility. Indeed, the authors conclude that no support was found for the age of acquisition hypothesis and speculate that the language specific effects which were uncovered might reflect different modes of cognitive processing associated with the two languages, or even aspects of the psychosocial dynamics of the interaction between subject and experimenter.

A possibility not considered by Furtado and Webster (1991) is that the nature of the tasks employed in the study (translation and reading) may also have contributed to the results. As Fabbro and Gran (1997) report, experimental studies of cerebral lateralization involving translation suggest that different strategies are employed when working across languages rather than within the same language. For example, Fabbro et al. (1990) studied fourth-year female students at a school for interpreters and found no significant cerebral asymmetry in linguistic functions for the first, second, or third language. The authors concluded
that the performance of complex verbal tasks such as interpretation involve the activation of attentive strategies and verbal and nonverbal cognitive processes which require the participation of both hemispheres. Similarly, Green et al. (1990, 1994) used simultaneous paraphrasing among other verbal tasks with a group of interpreters and found that the subjects displayed greater left hemisphere lateralization when paraphrasing in the same language than when interpreting. Thus, translation tasks may present problems for studies which focus on the issue of lateralization for second languages and the age of acquisition hypothesis. A similar issue may arise, though to a lesser degree, with respect to reading tasks as experimental studies, including some involving the concurrent task paradigm subjects (e.g., Waldie and Mosley 2000a, 2000b), have provided support for the notion of right hemispheric involvement in the reading process for monolingual subjects. It may be speculated, then, that the tasks involved go some way towards accounting for the results uncovered by Furtado and Webster (1991).

To recapitulate: the two studies with the largest samples (Sussman, Franklin, and Simon 1982, with groups of 40 and total n = 80; Green 1986, with groups of 24 and total n = 96) and therefore the best levels of statistical power, yielded the results most indicative of differential laterality effects. A third study with fewer subjects (Soares 1984, groups of 16 and total n = 32) presented some suggestive findings that might have attained significance with a larger sample. Two studies yielded results that are difficult to interpret given questions regarding sample selection and/or size (Hynd, Teeter, and Stewart 1980; Hall and Lambert 1988). One study appeared to have failed to control for practice effects, a severe methodological limitation (Hoosain and Shiu 1989). The final study (Furtado and Webster 1991) presented the strongest counterevidence to the notion of differential hemispheric involvement in first and second languages, although task related variables may have played a role in the results. Viewed in this manner, it can be argued that a measure of order does emerge from the maze of contradictory findings in the literature. It can further be argued that the fact that the two largest studies were the only ones to yield statistically significant results represents more than a coincidence, and arises from the aforementioned issue of statistical power.

The main purpose of the present study, therefore, was to investigate whether a study involving the concurrent task paradigm with a reasonably large sample of appropriately selected “early” and “late” second language acquirers could confirm the findings of similar earlier, reasonably large scale studies regarding right hemisphere recruitment for second language speech.
4. Method

4.1. Subjects

One hundred two high school and college students between the ages of fifteen and sixty-five (mean = 22.8 years) served as subjects in this study. In accordance with City University of New York policy, all subjects (or their legal guardians for those under eighteen years of age) gave written consent to participate, after being informed of the risks and benefits associated with the investigation. Thirty-four were native speakers of English, and the rest were “early” and “late” non-native speakers of English (34 subjects each). The age at arrival in the United States for these two groups ranged from four to twelve (mean = 8.5 years) for the early learners, and from thirteen to fifty-five (mean = 21.1 years) for the late learners. The mean length of residency in the United States for all non-native speakers was 6.6 years, and they reported using English 60.7% of the time on average. Fifteen native languages were represented. Russian speakers were by far the largest group (n = 36), followed by Chinese speakers (n = 6), and Spanish and Haitian Creole (n = 5 each). Other languages ranged from Arabic to Yoruba, with three or fewer speakers each. Female subjects outnumbered males substantially (73 to 29), approximately reflecting the college’s gender distribution (approximately 60% of undergraduate and 70% of graduate students at Brooklyn College are women). Table 1 summarizes the distribution of the subjects’ gender and average age.

All subjects were right handed as assessed by means of the Edinburgh Handedness Inventory (Oldfield 1971). All of the subjects wrote and drew with their right hand and reported a right side preference for at least eight of ten other activities: throwing a ball, brushing teeth, using scissors, a knife without a fork, a spoon, a broom (upper hand), striking a match (match), opening a box (lid), kicking, and using one eye.

4.2. Apparatus and procedure

Subjects were seen individually. They were first tested for handedness as described above and only right-handed subjects were selected. A brief questionnaire was then administered to obtain information concerning age, gender, native language, other languages and, for non-native speakers of English, age at

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<td>24.1</td>
</tr>
<tr>
<td>Early non-native</td>
<td>34</td>
<td>8</td>
<td>26</td>
<td>19.9</td>
</tr>
<tr>
<td>Late non-native</td>
<td>34</td>
<td>9</td>
<td>25</td>
<td>23.4</td>
</tr>
</tbody>
</table>
arrival and length of residence in the United States, and current patterns of native and English language usage.

From this point on, all instructions and tasks for the experiment were presented through a computer monitor and speakers; the program for doing this was created using the SuperLab Experimental Laboratory Software. The procedures described next were derived from the approach employed by Marcotte and Morere (1990) in a concurrent task study which investigated cerebral lateralization for speech in normal hearing and deaf adolescents. Subjects were informed that the purpose of the experiment was to see how fast they could tap a key while repeating words and sentences in order to see how fast they could do two things at once. The finger tap apparatus was a desk-top tally counter. The subjects were given 15 seconds to practice tapping the tally key with each index finger. Next, 11 experimental conditions were presented, each lasting 15 seconds:

1. Right-hand control: tapping without verbalization (RC)
2. Left-hand control (LC)
3. Right-hand tapping with verbal condition 1: “cat–dog–horse” (RV1)
4. Left-hand tapping with verbal condition 1 (LV1)
5. Right-hand tapping with verbal condition 2: “What can Bob do?” (RV2)
6. Left-hand tapping with verbal condition 2 (LV2)
7. Right-hand tapping with verbal condition 3: “Listening to music is enjoyed by many people” (RV3)
8. Left-hand tapping with verbal condition 3 (LV3)
9. Verbal condition 1 without tapping (V1)
10. Verbal condition 2 without tapping (V2)
11. Verbal condition 3 without tapping (V3)

Half the subjects within each group (natives, early and late non-natives) performed the tasks in order LC, RV1, RV2, RV3, V3, V2, V1, LV3, LV2, LV1 and RC, and the other half in reverse order to counter any practice and task order effects. Oral responses were recorded and subsequent word counts were carried out with the use of a transcriber. Finger tapping was recorded on the tally counter. The average time for completing a session (questionnaire administration, practice time, experimental tasks) was approximately 25 minutes.

Three independent variables were examined in this study: one between-subjects variable (group: native speakers, early and late non-native speakers of English), and two within-subjects variables, task condition (no verbal task, verbal tasks 1, 2, and 3) and hand used (left, right, none). Two dependent variables were examined: the number of words produced in 15 seconds, and the number of taps produced in 15 seconds. Since there were eleven tasks which yielded repeated measures of both dependent variables, the overall design of the study was a repeated measures ANOVA.
5. Results

As with Marcotte and Morere (1990), the results involving mean number of words uttered as the dependent variable revealed no effects for hand employed in the tapping tasks, and thus had no implications for lateralization patterns; therefore, the analysis presented below employs the mean number of taps as the sole dependent variable. A comparison of baseline tapping rates obtained from the regular order and reverse order sets showed substantial practice effects for right-hand tapping (means = 88.0 and 94.1, \( t[100] = 2.55, p = .006 \)) but not for left-hand tapping (means = 76.1 and 78.9, \( t[100] = -1.17, \text{ns} \)), consistent with previous findings (Furtado and Webster 1991; Kinsbourne and Hiscock 1983).

First, the tapping rates of male and female subjects were compared by means of the independent samples \( t \) test procedure. Consistent with previous research (Furtado and Webster 1991; Green et al. 1990; McGowan and Duka 2000; Waldie and Mosley 2000a), males (mean = 84.2) were found to tap faster than females (mean = 75.7, \( t[100] = 3.35, p = 0.001 \)). Next, to determine the cerebral lateralization patterns for speech control across the subjects, a 3 (group: native, early non-natives, late non-natives) \( \times \) 2 (hand: left, right) \( \times \) 4 (task: no verbal task, V1, V2, V3) repeated measures ANOVA was computed, with mean number of taps produced in 15 seconds as the dependent variable. The power of a \( F \) test of 3 \( \times \) 2 \( \times \) 4 interaction effects with a sample size of 102 at alpha = .05 is .45 against a medium effect size and .89 against a large effect size (Cohen 1977: 321, Table 8.3.17).

The results (as shown in Table 2) showed significant main effects for hand (\( F[1,99] = 178.65, p < 0.001 \)), task (\( F[3,297] = 84.11, p < 0.001 \)), and group (\( F[2,99] = 4.47, p = 0.014 \)). Significant two way interactions were also found: task by group (\( F[6,297] = 2.17, p < 0.05 \)), and task by hand (\( F[3,297] = 8.94, p < 0.001 \)). As would be expected, all subjects tapped faster with their right hand (mean on all tasks = 83.1) than with their left hand (mean on all tasks = 73.2). Also as would be expected, tapping rates for all subjects declined from baseline tapping without vocalization (mean for both hands = 84.3), to tapping during concurrent tasks (V1 mean = 75.2; V2 mean = 76.5; V3 mean = 76.6). Among groups, native subjects (mean = 82.7) tapped faster than early non-natives (mean= 77.5) and late non-natives (mean = 74.3). However, even though baseline tapping rates were highest on both hands for natives, followed by early and late non-native subjects respectively, post hoc tests using Tukey’s Honestly Significant Difference (HSD) procedure yielded no significant differences between any two groups for either the left- or right-hand baseline tapping rates (alpha = 0.050).

Of relevance to the issue of lateralization patterns, the three-way interaction effect between group, task, and hand reached significance (\( F[6,297] = 2.15, \)
Table 2. Mean number of taps produced in 15 sec and standard deviations as a function of task, hand and group

<table>
<thead>
<tr>
<th>Verbal task</th>
<th>No verbal task</th>
<th>V1: “cat–dog–horse”</th>
<th>V2: “What can Bob do?”</th>
<th>V3: “Listening to music is enjoyed by many people.”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand</td>
<td>L</td>
<td>R</td>
<td>L</td>
<td>R</td>
</tr>
<tr>
<td>Native speakers</td>
<td>M</td>
<td>79.6</td>
<td>95.5</td>
<td>76.3</td>
</tr>
<tr>
<td>Speakers SD</td>
<td>12.0</td>
<td>11.5</td>
<td>13.9</td>
<td>14.2</td>
</tr>
<tr>
<td>Early non-natives</td>
<td>M</td>
<td>77.5</td>
<td>88.6</td>
<td>71.0</td>
</tr>
<tr>
<td>SD</td>
<td>11.1</td>
<td>13.6</td>
<td>12.6</td>
<td>14.3</td>
</tr>
<tr>
<td>Late non-natives</td>
<td>M</td>
<td>75.4</td>
<td>89.0</td>
<td>66.1</td>
</tr>
<tr>
<td>SD</td>
<td>13.9</td>
<td>10.8</td>
<td>13.0</td>
<td>16.1</td>
</tr>
<tr>
<td>All Subjects</td>
<td>M</td>
<td>77.5</td>
<td>91.1</td>
<td>71.1</td>
</tr>
<tr>
<td>SD</td>
<td>12.4</td>
<td>12.3</td>
<td>13.7</td>
<td>14.9</td>
</tr>
</tbody>
</table>

Table 3. Mean percentage disruption scores for group × hand interactions

<table>
<thead>
<tr>
<th>Group</th>
<th>Right hand</th>
<th>Left hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native speakers</td>
<td>10.42</td>
<td>3.98</td>
</tr>
<tr>
<td>Early non-natives</td>
<td>9.72</td>
<td>8.21</td>
</tr>
<tr>
<td>Late non-natives</td>
<td>15.07</td>
<td>10.38</td>
</tr>
</tbody>
</table>

Post hoc tests revealed no significant differences between any two groups in decrease in the right-hand tapping rate under dual task conditions, but the Tukey HSD procedure did yield a significant difference between the native and late non-native subjects in decrease in the left-hand tapping rate under concurrent task conditions (alpha = 0.050), and produced two homogeneous subsets: (natives and early non-natives) and (early and late non-natives). Tapping rate decreases are shown in Table 3. These findings suggest greater right cerebral involvement under the concurrent task condition for late non-native subjects (10.38 % left-hand decrease) compared to native subjects (3.98 % left-hand decrease), with the early non-native group exhibiting an intermediate value (8.21 % left-hand decrease) positioned between the other two groups without differing in a statistically significant way from either.
6. Discussion

It has already been argued that the findings of the current study are consistent with the age of acquisition hypothesis of increased right hemisphere involvement in multilinguals during speech production, and that they complement the findings of earlier lateralization studies based on the concurrent task design which also used relatively large samples. Given the increasing importance of neuroimaging studies and the aforementioned issues of validity and reliability of behavioral indices of laterality, a further question well worth posing is whether results such as these also complement the findings from research involving various neuroimaging techniques. A brief review of several recent imaging studies is therefore offered.

Interestingly, a consistent pattern of results is not immediately apparent from the studies involving the event-related potentials (ERP) technique, positron emission tomography (PET), and functional magnetic resonance imaging (fMRI), which have investigated the cerebral representation of second languages. A number of studies find no evidence of right hemisphere involvement in second languages but differ as to whether the left hemisphere areas involved overlap entirely or partially for first and second languages. For instance, Klein, Zatorre et al. (1995) used positron emission tomography with repetition, synonym generation, and translation tasks involving the oral production of single words to investigate 12 native speakers of English who had acquired French after the age of five (mean age = 7.3 years), and uncovered no evidence that the second language was represented differently in the left hemisphere from the first. In a functional magnetic resonance imaging study involving silent word-generation tasks, Yetkin et al. (1996) tested 5 male subjects who, in addition to their native language, spoke fluently in a second language and had limited proficiency in a third language. In this case, more extensive left hemisphere activation was measured for the languages in which the subjects were less proficient. Unfortunately, age of acquisition was not reported.

Perani et al. (1996) used positron emission tomography to study brain activity in 9 bilingual adult Italian subjects with a moderate command of English learned at school after the age of seven (or after the age of ten, as reported for the same group of subjects in Perani et al. 1998) as they listened to stories, and uncovered different patterns of left hemisphere activation for the native and non-native languages. Kim et al. (1997) used functional magnetic resonance imaging to investigate 9 male and 3 female adult, fluent multilinguals; six were exposed to two languages during infancy and the other six in late childhood (mean age of initial exposure = 11.2 years). The task involved silent sentence generation and the results indicated spatial separation within Broca’s area between native and late second languages. Perani et al. (1998) studied 9 adult native speakers of Italian who had learned English at school after the age of ten.
years and spent 1–6 years in an English speaking country, eventually attaining a high level of proficiency, and 12 Spanish-Catalan fluent, early bilinguals who were also male adults. This research used positron emission tomography with listening tasks. Results showed a lack of differences between the cerebral activations associated with first and second languages. In a cued word-generation study, Chee, Tan, and Thiel (1999) tested 15 early and 9 late Mandarin-English bilinguals. The former had been exposed to L2 in spoken and written form by age six, while the latter had their first L2 exposure at or after the age of twelve years. Results showed similar patterns of brain activation for both languages in both groups. Chee et al. (1999) administered a task involving the comprehension of written sentences to 14 Mandarin-English bilinguals exposed to both languages prior to the age of six, and concluded that common neuroanatomical regions were utilized during the processing of visually presented sentences in both languages.

Three studies did uncover patterns of bilateral activation for second languages. Weber-Fox and Neville (1996) carried out an event-related potentials study involving 61 adult Chinese-English bilinguals with a wide range of age of acquisition (from 1–3 years to after sixteen years of age), using a task which required subjects to judge the correctness of 240 visually presented sentences of English. Half of the sentences were correct, while half violated semantic or syntactic rules. Results indicated that when performing syntactic judgments, early learners displayed characteristic left hemisphere event-related potentials components, but that later learners showed significantly more bilateral activation. In a functional magnetic resonance imaging study, Dehaene et al. (1997) investigated 8 adult French speakers who had learned English at school after the age of seven using a listening task and found that second but not first language listening activated both left hemisphere and right hemisphere regions, although individual subjects varied greatly in degree of right hemisphere involvement. Finally, Calabrese et al. (2001) also used functional magnetic resonance imaging in a study of word generation in bilinguals and found that both first and second language use elicited left prefrontal activity, but that second language use elicited additional right prefrontal activity.

In examining the findings from several neuroimaging experiments including most of those mentioned above and a few others, different observers have reached differing conclusions. Thus, Neville and Bavelier (1998) and Newport, Bavelier, and Neville (2001) offered the following synthesis: results indicate strong left hemisphere activation for L1 in bilinguals in general and for L2 in early bilinguals. Late second languages are subserved by neural systems which are partially or completely nonoverlapping with those for L1, and these systems for later second languages tend to show a lesser degree of lateralization and a greater degree of variability among individuals. This writer essentially subscribes to that view. On the other hand, Abutalebi, Cappa, and
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Perani (2001) concluded that attained second language proficiency is a more important determinant of the cortical representation of second languages than is the age of acquisition. For example, in considering several language production experiments, the authors suggested that the reason Kim et al. (1997) found differential left hemisphere activation in late bilinguals, while Chee, Tan, and Thiel (1999) uncovered no such differences, was the result of the lower second language proficiency of the Kim subjects compared to the higher proficiency exhibited by the Chee subjects. Yet, what little information is given by either study concerning the subjects’ language proficiency does not readily lend itself to such an interpretation. Thus, Kim et al. (1997: 174) report “a high standard for fluency” for their “late” bilingual subjects and state that “all subjects reported approximately equal fluency and frequent usage in each language at the time of testing”. On the other hand, Chee, Tan, and Thiel (1999: 305) report that for most of the late subjects, “writing skills in English still remain superior to speaking and listening skills”. It is difficult to see on what basis the latter subjects could be judged as markedly more proficient than the former ones.

To further support their claim that language production tasks are subserved by a common neural network in late bilinguals if they are highly proficient in both languages, Abutalebi et al. (2001) also cite Klein, Milner, et al. (1995) and Yetkin et al. (1996). However, as previously pointed out, Yetkin’s study does not report the age of L2 acquisition of its subjects, and Klein’s study refers to L2 acquisition after age five as “late” bilingualism. The authors also examine several studies involving language comprehension tasks which suffer from similar shortcomings. For example, “late” bilingualism is variably defined as L2 exposure not before age 7 (Perani et al. 1996; Dehaene et al. 1997), at a mean age of 8.8 years (Price et al. 1999), and after age ten (Perani et al. 1998). None of these operational definitions meets the criterion set earlier in this paper that “late” acquisition ought to begin indisputably after puberty, in the late teens. In short, “late” acquisition is “adult” acquisition, and in the absence of a sample which presents the appropriate age distribution characteristics, it is effectively not possible to disentangle the age factor from the language proficiency factor.

It appears, then, that the results from functional imaging and electrophysiological techniques pose problems of consistency not unlike those relating to behavioral techniques. Indeed, while the neuropsychological investigation of the cortical representation of first and second languages has undergone a profound transformation with the advent of neuroimaging techniques, it is also clear that a number of technical limitations still need to be resolved. These include, among others: problems in the subtractive positron emission tomography methodology (Poeppel 1996), insufficiency of the spatial and/or time resolution not only of event-related potentials techniques but also of functional magnetic resonance imaging and positron emission tomography to detect subtle linguistic processes (Hernandez, Martinez, and Kohnert 2000; Demonet and
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Thierry 2001), and issues of robustness and reliability of language lateralization indices obtained with functional magnetic resonance imaging (Rutten et al. 2002). In addition, the issues of sample size and composition discussed in this paper, particularly with respect to selecting subjects with appropriate language histories and appropriately defined “early” and “late” ages of acquisition, still need to be properly addressed.

To return to the question posed earlier, namely whether the results from the present study are convergent with findings from neuroimaging studies, the answer can only be a tentative one. It stands out that, just as with the concurrent task literature, it is the brain mapping study with the largest sample size and the widest range of age at acquisition represented among the subjects, Weber-Fox and Neville (1996), which provides the strongest evidence for differential lateralization. This suggests that the case for right hemisphere recruitment in the processing of late second languages remains open and deserving of future investigation. At the same time, the current evidence is clearly not sufficient to either accept or reject the proposal by Abutalebi et al. (2001: 187) that “in the case of late bilinguals, [italicized in the original] the degree of language proficiency seems to be a critical factor in shaping the functional brain organization of languages”, and that case also remains open. The remark by Zatorre (1989) that the contradictions in the clinical and experimental evidence concerning differential lateralization result from methodological, analytical, and conceptual shortcomings seems to apply with equal relevance to the evidence from imaging studies. His conclusion that the bilingual brain nevertheless continues to present a very rich resource for assessing various hypotheses concerning neurolinguistic organization seems equally apt, as does the contention by Hiscock and Kinsbourne (1995) that behavioral laterality methods remain directly relevant to brain physiology and are complementary to biomedical methods rather than competitive, providing an opportunity for the construction of a network of convergent facts.

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Note

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