

INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

UMI

A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor MI 48106-1346 USA
313/761-4700 800/521-0600

7

CONCURRENT PROCESSING OF FACES AND SPEECH IN RELATION TO
HEMISPHERIC LATERALIZATION

by
Phyllis M. Kittler

A dissertation submitted to the Graduate Faculty
in Psychology in partial fulfillment of the
requirements for the degree of Doctor of
Philosophy, The City University of New York.

1997

UMI Number: 9720105

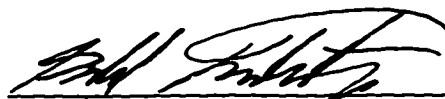
UMI Microform 9720105
Copyright 1997, by UMI Company. All rights reserved.

**This microform edition is protected against unauthorized
copying under Title 17, United States Code.**

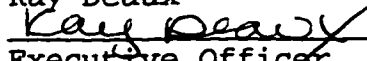
UMI
300 North Zeeb Road
Ann Arbor, MI 48103

This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

1-6-97
DATE


Chair of Examining Committee

1-13-97
DATE

Kay Deaux

Executive Officer

Gerald Turkewitz

Martin Chodorow

Virginia Valian

Supervisory Committee

THE CITY UNIVERSITY OF NEW YORK

Abstract

CONCURRENT PROCESSING OF FACES AND SPEECH IN RELATION TO
HEMISPHERIC LATERALIZATION

by

Phyllis M. Kittler

Advisor: Professor Gerald Turkewitz

In recognition of the ecological importance of the talking face and its potential role in the development of hemispheric lateralization, descriptive studies were undertaken to examine the effects of concurrent face and speech processing on hemispheric lateralization.

In Study 1, four faces were presented in tachistoscopic fashion via computer. Responses were 366 msec faster in the right hemisphere. The majority of subjects exhibited a right hemisphere processing speed advantage, but those who were relatively faster in the left hemisphere were more accurate.

In Study 2, a spoken word was incidentally presented concurrently with each face to simulate bimodal recognition of an individual. With concurrent processing of faces and related speech, the right hemisphere speed advantage disappeared and the group that was faster in the left hemisphere was no longer superior on face recognition.

However, this group was superior on speech recognition. There were positive correlations between face and speech recognition performance for both hemispheres.

The third study examined the effects of having particular relationships between the faces and speech. Presenting unrelated speech with faces had the same effects on hemispheric advantage as presenting related speech. However, right hemisphere face recognition was no longer positively correlated with speech recognition. Observations suggesting a trade off in attention between faces and speech, for only the right hemisphere, are discussed.

Speech and face recognition performance for Studies 2 and 3 unexpectedly indicated that subjects did "two things at once"; even though, the speech was incidentally presented. This finding was explored in the final two studies. It was hypothesized that the special nature of the face speech combination was responsible. Processing of the non-ecological combination of silent inverted faces and inverted faces with speech was tested and provided no evidence for this hypothesis.

Two methodological issues were raised by these studies. When faces were inverted with task difficulty adjusted, there was no indication of a typically reported unequal

decline in right hemisphere performance suggesting a confound in the face inversion literature between task complexity and inversion. Secondly, use of both reaction time and accuracy as measures of lateralization resulted in a number of disassociations between them suggesting that inferring equivalent advantages from these two measures is unwarranted.

Acknowledgments

My thanks extend to the following individuals:

Gerald Turkewitz, for planting the thought that I might actually earn a Ph.D., for supporting me through every step toward that goal and, most importantly, for sharing with me his enthusiasm for the world of ideas and research.

Sheila Chase for graciously opening her lab to physically sustain my research, for giving my hard won subjects priority over her own busy schedule and for providing expertise and encouragement during times when the process was frustrating.

Elaine Hall, my "comrade in arms", for being a good friend and for generating so much inspiration and optimism, always generously seasoned with her many practical suggestions.

My children - Sara, Alex and Devin - who have made the process longer than it might have been, but who have also made it seem more worthwhile and who have given much joy throughout.

Tom Tilitz, my husband, who has exhibited remarkable patience and endurance in the many years of living with a "gradual" student and who, through his wide ranging knowledge, has helped keep me in touch with the rest of the world.

TABLE OF CONTENTS

ABSTRACT	iii
ACKNOWLEDGMENTS	vi
TABLE OF CONTENTS	vii
LIST OF TABLES	ix
LIST OF FIGURES	xi
 CHAPTER 1	
INTRODUCTION	1
BACKGROUND	8
 CHAPTER 2	
WHAT IS THE RELATIONSHIP BETWEEN THE HEMISPHERES FOR PROCESSING OF FACES IN THE ABSENCE OF SPEECH?	
STUDY 1 - FACE RECOGNITION NO SPEECH	
INTRODUCTION	33
METHOD	33
RESULTS	41
STUDY 1 SUMMARY OF OBSERVATIONS	52
DISCUSSION	53
 CHAPTER 3	
WHAT PROCESSING ALTERATIONS OCCUR WHEN RELATED SPEECH IS PRESENTED CONCURRENTLY WITH FACES?	
STUDY 2 - FACE RECOGNITION WITH RELATED SPEECH	
INTRODUCTION	58
METHOD	60
FACE RECOGNITION RESULTS	66
HOW WELL DO PARTICIPANTS DO TWO THINGS AT ONCE?	
INTRODUCTION	76
METHOD	77
DELAYED SPEECH RECOGNITION RESULTS	81
STUDY 2 SUMMARY OF OBSERVATIONS	93
DISCUSSION	95

CHAPTER 4

DOES CONCURRENT PROCESSING OF UNRELATED FACES
AND SPEECH RESULT IN DIFFERENT EFFECTS FROM
THOSE PRODUCED BY PROCESSING RELATED SPEECH?

STUDY 3 - FACE RECOGNITION WITH UNRELATED
SPEECH

INTRODUCTION	112
METHOD	114
FACE RECOGNITION RESULTS	115
HOW WELL DO PARTICIPANTS DO TWO THINGS AT ONCE?	
INTRODUCTION	122
DELAYED SPEECH RECOGNITION RESULTS	122
STUDY 3 SUMMARY OF OBSERVATIONS	137
DISCUSSION	139

CHAPTER 5

IS THE SPEECH FACE COMBINATION SPECIAL?
WHEN IS A FACE NOT A FACE? WHEN IT IS INVERTED.

STUDY 4 - INVERTED FACE RECOGNITION NO SPEECH

STUDY 5 - INVERTED FACE RECOGNITION RELATED
SPEECH

INTRODUCTION	146
STUDY 4 METHOD	149
STUDY 4 INVERTED FACE RECOGNITION RESULTS	153
STUDY 4 SUMMARY OF OBSERVATIONS	160
INTRODUCTION TO STUDY 5	161
STUDY 5 METHOD	161
STUDY 5 INVERTED FACE RECOGNITION RESULTS	163
STUDY 5 SPEECH RECOGNITION RESULTS	173
STUDY 5 SUMMARY OF OBSERVATIONS	179
DISCUSSION	180

CHAPTER 6

FINAL SUMMARY OF OBSERVATIONS	187
GENERAL DISCUSSION	191

APPENDIX A: ADDITIONAL DATA AND ANALYSES	209
APPENDIX B: DETAILED PROCEDURAL INFORMATION	225
APPENDIX C: SUMMARY OF NEW QUESTIONS	229
APPENDIX D: FEMALE AND MALE DATA: STUDIES 1-3	235
REFERENCES	237

LIST OF TABLES

Table 1	Study 1: Individuals Grouped by Processing Speed Advantage	p. 50
Table 2	Study 1 & Study 2 Compared: Face Recognition Reaction Time in LVF and RVF	p. 70
Table 3	Study 1 & Study 2 Compared: Face Processing - Individuals Grouped by Processing Speed Advantage	p. 75
Table 4	Study 2: Performance on Delayed Speech Recognition	p. 85
Table 5	Study 2: Pearson Correlations Between Face and Speech Recognition Accuracy	p. 91
Table 6	Study 2: Individuals Grouped by Processing Speed Advantage Percent Correct by Word Type on Delayed Speech Recognition	p. 92
Table 7	Study 1 - Study 3 Compared: Face Recognition Reaction Time in LVF and RVF	p. 118
Table 8	Study 1 - Study 3 Compared: Individuals Grouped by Processing Speed Advantage	p. 121
Table 9	Study 2 & Study 3 Compared: Performance on Delayed Speech Recognition	p. 124
Table 10	Study 2 & Study 3 Compared: Pearson Correlations Between Face and Speech Recognition Accuracy for LVF ADV and RVF ADV Groups	p. 128
Table 11	Study 2 & Study 3 Compared: Individuals Grouped by Processing Speed Advantage - Percent Correct by Word Type on Delayed Speech Recognition	p. 129

Table 12	Study 2 & Study 3 Compared: Face Processing - Individuals Grouped by Speech Recognition Accuracy	p. 135
Table 13	Study 3: Individuals Grouped by Speech Recognition Accuracy - Top and Bottom Quartile	p. 136
Table 14	Study 1 - Study 4 Compared: Face Recognition Reaction Time in LVF and RVF	p. 156
Table 15	Study 1 - Study 4 Compared: Individuals Grouped by Processing Speed Advantage	p. 159
Table 16	Study 1 - Study 5 Compared: Accuracy in LVF and RVF on Face Recognition	p. 166
Table 17	Study 1 - Study 5 Compared: Face Recognition Reaction Time in LVF and RVF	p. 167
Table 18	Study 1 - Study 5 Compared: Pearson Correlations Between Speed and Accuracy on Face Recognition	p. 170
Table 19	Study 1 - Study 5 Compared: Individuals Grouped by Processing Speed Advantage - Accuracy in LVF and RVF on Face Recognition	p. 171
Table 20	Study 1 - Study 5 Compared: Individuals Grouped by Processing Speed Advantage - Reaction Time in LVF and RVF on Face Recognition	p. 172
Table 21	Study 2, Study 3 and Study 5 Compared: Performance on Delayed Speech Recognition	p. 174
Table 22	Study 2, Study 3 and Study 5 Compared: Pearson Correlations Between Face and Speech Recognition Accuracy	p. 177
Table 23	Study 2, Study 3 and Study 5 Compared: Individuals Grouped by Processing Speed Advantage - Percent Correct by Word Type on Delayed Speech Recognition	p. 178

LIST OF FIGURES

Figure 1	Study 1: Face Stimuli	p. 39
Figure 2	Face Recognition: Single Trial Time Line	p. 40
Figure 3	Study 1: Face Recognition Reaction Time in LVF and RVF	p. 45
Figure 4	Study 1: Accuracy on Face Recognition in the LVF and RVF for Processing Speed Advantage Groups	p. 51
Figure 5	Study 2: Auditory and Face Stimuli	p. 64
Figure 6	Face Recognition with Speech: Single Trial Time Line	p. 65
Figure 7	Distractor Words Used in Delayed Auditory Recognition Session	p. 80
Figure 8	Study 4: Inverted Face Stimuli	p. 152

CHAPTER 1

INTRODUCTION

Beginning with the split brain studies of Roger Sperry, a great deal of fascinating research has been done examining the lateralization of face, speech, and more generally, auditory processing. However, this work has primarily been done on each modality in isolation. While this has been a very feasible and productive approach, it misses some ecologically important situations. Consider, for instance, the processing of a talking face - processing which is ubiquitous, developmentally and socially important and unique to our species. A talking face bimodally engages two particularly human forms of information processing, face processing and speech processing, in the apprehension of the same event. Each one of these, even when considered alone, is quite special, special in terms of evolutionary history, proficiency, ontogeny and social role.

Humans process faces extremely efficiently and with impressive memorial capabilities. Special attention to face like stimuli and faces can be demonstrated very early in infancy and seems to be present even at birth (Morton & Johnson 1991, Slater, 1993). Preference for the mother's face appears within the first days of life, suggesting an

early emerging ability to recognize particular individuals (Morton, 1993). Some researchers argue that due to its early appearance and unusual characteristics face processing is a unique cognitive ability with specialized brain areas, beyond those required for general object recognition, dedicated to face processing tasks. While the debate about its uniqueness is unresolved, it is generally accepted that face processing is at least special among human cognitive abilities (Ellis & Young, 1989).

The processing of speech is likewise considered to be a distinctive cognitive ability. In fact, speech processing is more definitively accepted as a uniquely human, and unique for humans, ability. It is sometimes invoked as the cognitive ability which most separates us from other species. Like face processing, it has an exceptional developmental history. It is in evidence in early infancy and there is growing support for, and understanding of, its prenatal beginnings (e.g., DeCasper & Spence, 1986).

In addition to the overall special nature of face and speech processing, both have a unique relationship to considerations of hemispheric lateralization. When much of the scientific world still believed in the equipotentiality of the two halves of the brain, it was Dax and Broca's localization of language, in the left hemisphere of right handed individuals, that began to change this view. When so

called "split brain individuals" were created as a result of performing commissurotomies that severed the millions of connecting fibers between the left and right hemispheres, the most dramatic observations were those related to having a talking left hemisphere that could not talk about - did not even have direct access to - information that was available to the non-talking right hemisphere.

More recently, a left hemisphere advantage for lipreading and American Sign Language has been observed and further strengthens the evidence for language lateralization in the left hemisphere. A left hemisphere advantage for language processing has, thus, been extended to the more broadly defined category of language systems that includes visuospatial modes of language representation (Campbell, 1989; Corina, Vaid & Bellugi, 1992; Sacks, 1989).

In addition to language information, the speech signal contains a voice component. This too has been studied in relation to hemispheric lateralization. Voice processing has sometimes been found to exhibit an advantage opposite that of language processing, namely a right hemisphere advantage (Ellis, 1989). This is especially true for the processing of an unfamiliar voice (Riley & Sackheim, 1982). The voice component of the speech signal, like the face itself, often carries emotional information and may serve the function of identification or recognition of an

individual. In relation to this, a small group of patients has been observed for whom simultaneous impairment of voice and face recognition is associated with right hemisphere damage (Van Lancker & Canter, 1982).

While studies of face processing have not resulted in findings as dramatic as those from studies of the language component of speech, and while face processing has not so robustly favored either hemisphere, there is convergent evidence that points to a greater role for the right hemisphere in dealing with faces. And face processing has been studied extensively in the lateralization literature, often in an attempt to provide a counterpoint to the study of the left hemisphere's verbal abilities.

Given this background, it is surprising that there has been little exploration of the simultaneous processing of faces and speech in relation to hemispheric lateralization. The current studies were undertaken to commence filling this void. Thus, the aim of these studies was to begin to describe the effects on information processing between the left and right hemispheres of simultaneously encountering a face and speech, as occurs when processing a talking face. These studies were, from the very beginning, intended to be descriptive. It was felt that without any specific precedent in the literature hypothesis formation would be quite premature and not particularly useful at this time.

Within this context, a number of questions, rather than hypotheses, were considered pertinent. When face processing and speech processing proceed concurrently, do the underlying cognitive functions exhibit the same lateral advantage as when they occur in isolation? Or does simultaneous processing in two modalities result in differing strategies of processing with concomitant alterations in hemispheric advantage? Furthermore, are there alterations in hemispheric advantage when faces and speech become familiar and related, as normally occurs when one learns to bimodally recognize particular individuals?

Implied in these general questions is the expectation of some degree of change in patterns of lateralization when faces and speech are processed concurrently as opposed to when faces are processed alone. This expectation is not without foundation. While it is true that there is a characteristic right hemisphere advantage for face processing and a characteristic left hemisphere advantage for the processing of the language content of speech, it has also been shown that hemispheric specialization among normals is somewhat dynamic. Among the factors that have already been found to influence it are the characteristics of the stimuli (Sergent, 1983), differences among individual processing styles (Levine, Banich & Koch-Weser, 1984), processing approaches (Ross & Turkewitz, 1982) and both

macro and micro level experience or familiarization (Bever & Ciarello, 1974; Kinsbourne & Bruce, 1987; Kittler, Turkewitz & Goldberg, 1989). Considering these findings, questions about alterations in hemispheric lateralization in concurrent face and speech processing are justified. It seems reasonable to expect that the resource demands and multimodal nature of concurrent face and speech processing might also result in alterations of the characteristic hemispheric advantage for this processing.

The questions just described are directly relevant to a basic understanding of the human cognitive abilities of face and speech processing as well as to theories of resource sharing between the hemispheres. They were inspired by and are also related to theories concerning the development of hemispheric specialization. A brief description of these theories will be undertaken in order to fully explain the origins of the current research.

It has been proposed that a differential growth rate of the cerebral hemispheres, the right initially growing faster than the left, in combination with a preferential availability of low spatial frequency information in the infant, contributes to the development of selective sensitivity for this information in the right hemisphere (Sergent, 1987). More specifically, it has been suggested that the right hemisphere develops a specialty for

processing faces, particularly the low spatial frequency information contained in them, due to the combination of uneven hemispheric growth and availability of face stimuli (de Schonen, Dereuelle, C., Mancini, J. & Pascalis, O., 1993; de Schonen & Mathivet, 1989; Turkewitz, 1989).

In an elaboration of this idea, it is the processing of a talking face, in particular, which serves as the source for the development of this hemispheric specialization (Turkewitz, 1990). Limited accommodation of the infant visual system makes it very likely that when an infant perceives a face, it will be a talking face. Prenatally the left hemisphere has already developed a specialty for the processing of speech (Turkewitz, 1988). This increases the likelihood that the visual information in the talking face will be processed in the right hemisphere since the left hemisphere is already subserving the speech processing.

It was felt that a description of concurrent face and speech processing in relation to lateralization in the adult might help elucidate these developmental views and possibly suggest new questions that could be applied to the study of infants. It is, however, recognized that the many differences between adults and infants, including the fact that most adults have fully functioning corpus callosums and young infants do not, make direct generalization from the adult to the infant tenuous.

BACKGROUND

Although the history of perceptual research has been dominated by the study of unimodal processing of stimuli, it has also been recognized that, for humans, the case of a single sensory system being stimulated by a single stimulus at a time is quite rare and primarily restricted to the laboratory. As a result, many theoretical and experimental approaches have arisen which attempt to address the fact that real life information processing usually involves doing or perceiving more than one thing at a time, oftentimes in more than one sensory modality. These approaches range from studying the effects of a passively present secondary stimulus on perception of another stimulus to observing simultaneous performance on multiple tasks in multiple sensory modalities.

Common to many of these approaches is an interest in the effect of the concurrence or presence of additional stimuli on performance. For instance, in signal detection research, a typical paradigm is to study the changes in the detectability of a visual or auditory signal both in the presence and in the absence of stimulation in another modality. This heteromodal stimulation often results in improved signal detection, especially if the detection task

is boring and if the secondary stimulation meaningful (Stanislaw, 1988).

Everyday experience tells us that enhancement of performance through concurrent stimulation is not limited to the type of discrete information processing represented in signal detection studies. Experimental evidence bears this out. Bimodal stimulation, particularly when stimuli are related, has sometimes been observed to improve performance in experimental instances of broader information processing. For instance, in studies of television watching, comprehension and recall of a news program (Stine, Wingfield & Myers, 1990) and understanding by children of an educational T.V. program (Rolandelli, Wright, Huston & Eakins, 1991) were shown to have been enhanced when both audio and visual components were present and were semantically related to one another. Likewise, the presence of both a face and voice, as opposed to either a face or a voice alone, resulted in more accurate judgements in criminal line-ups (Melara, DeWitt-Rickards & O'Brien, 1989). In speech perception, seeing speech, i.e. lipreading, while simultaneously hearing speech can result in better comprehension, especially in situations where the auditory signal is degraded or where there is competing noise (Campbell, 1989). In these types of studies, the concurrence effects are discussed in terms of bimodal or

bisensory augmentation, stimulus redundancy, multimodal facilitation or multimodal enhancement.

On the other hand, most of us know that writing a letter while having a conversation on the telephone and listening to music is quite difficult. This type of effect - interference - has also been studied experimentally. In just one instance, from an immense body of literature, the naming of visually presented pictures (patterned after the Stroop task) was slowed by the simultaneous presentation of various categories of auditory stimuli. The categories included unrelated words, words phonologically similar to the picture names, and associates or opposites of the picture names. This effect was characterized by the researchers as cross-modal interference (Schriefers & Meyer, 1990).

In general, and in an admittedly oversimplified way, the framework and literature into which a concurrence is placed, i.e. interference or facilitation, is often determined, after the fact, based upon such performance results. If performance improves, the concurrence is more likely to be considered in terms of multimodal processing, multimodal facilitation or bimodal stimulus redundancy. If the effect on performance is detrimental, then the concurrence is more likely to be viewed in terms of attention, divided attention or interference. As the

research moves from examining simultaneously occurring stimuli to studying the effects of simultaneous tasks, even the apriori discussion is more likely to become a discussion concerned with divided attention, processing capacity and resource theory. This is mostly due to the fact that instances of decreased performance in concurrent versus single task situations are extremely prevalent and can most often be predicted in advance. In concurrent task paradigms, the situations of special interest become those where two tasks can be accomplished simultaneously without a detriment to the performance of either (Pashler, 1990). In these rare instances the effect is more likely to be characterized as time sharing or automatic processing.

To be sure, not all work on the processing of concurrent stimuli and multimodal stimulation is defined primarily by performance effects. Some approaches have been more concerned with how perceiving an object or event in one modality qualitatively changes its perception in another. For example, it has been shown that newborns' preferences for visual stimuli of differing intensities can be altered by prior or concurrent auditory stimulation (Turkewitz, Lewkowicz & Gardner, 1983). In another example, in a phenomenon known as the visual capture effect, it has been shown that when simultaneous visual and auditory stimuli provide different sensory information on the location of a

sound, the visual information tends to dominate the judgment (see Rose & Ruff, 1987 for review). Similarly, visual stimulation that occurs randomly may be perceived as being rhythmically synchronized when presented simultaneously with a clearly rhythmical auditory stimuli (see Rose & Ruff, 1987 for review).

Another important aspect of this non-performance oriented approach to concurrent multimodal stimulus processing is the exploration of what is known as cross-modal matching. This refers to the recognition or perception that information being simultaneously processed in multiple sensory modalities represents different dimensions of the same object or event. This approach to concurrent processing of stimuli has been especially relevant in developmental studies and is often examined by presenting asynchronous or incongruous events and determining whether the infant recognizes the asynchrony or incongruity. For instance, it has been shown that infants as young as four months old can detect cross-modal equivalence in the perception of seen and heard vowel sounds. This was indicated by a preference for looking at a videotape of a talking face which was synchronized with a simultaneously presented sound track as opposed to an asynchronous one (Kuhl & Meltzoff, 1984). The effect was specific to the spectral information in the sound track and

was not manifested in the presence of temporal synchrony alone. A similar result was observed with 5 to 6 month olds when presented with consonant-vowel-consonant-vowel disyllables, except that it was only observed when the babies were looking to their right (MacKain, Studdert-Kennedy, Spieker & Stern, 1983). This led the authors to infer a left hemisphere advantage for such cross-modal language processing.

With this broader view of concurrence research in mind, the following question now seems appropriate: how has the study of hemispheric lateralization reflected considerations of doing or processing more than one thing at a time? This question is more directly relevant to the current studies. There are two main ways in which this question has been reflected in the lateralization literature. First is in the dichotic listening paradigm. Second is in an approach best exemplified by the fingertapping paradigm. Both of these approaches have become more of a means to an end, i.e. as a vehicle for ascertaining hemispheric specialization for particular processing, than as an indication of an interest in the effects of concurrent stimulation on hemispheric lateralization. Some exceptions to this emphasis exist, particularly in the theoretical work, to be discussed later, of Marcel Kinsbourne, Martha Polson and Alinda Friedman.

In the dichotic listening paradigm, a different auditory message is simultaneously presented to each ear. Applying this procedure results in better reporting of verbal stimuli presented to the right ear as compared to the left ear. Such differences do not emerge as clearly, if at all, when the messages are presented to one ear at a time. In 1961, Doreen Kimura proposed a model to explain this concurrence effect. She proposed that during such demanding information processing, transmission on the ipsilateral pathways between the ears and the cerebral hemispheres is suppressed and transmission on the contralateral pathways dominates (Springer & Deutsch, 1989). Thus, a dichotically presented message in the right ear is initially transmitted only to the left hemisphere and vice versa. This accounts for the originally observed right ear advantage. According to Kimura's model, the right ear information is being projected directly to the language dominant left hemisphere. The acceptance of this interference model, which has since been further corroborated by studies with commissurotomy subjects, has led to the use of the dichotic listening technique as the primary tool in the extensive literature on auditory processing and hemispheric lateralization.

Like dichotic listening, the concurrent task approach, as exemplified in fingertapping studies, has also been used as a tool for the assessment of hemispheric advantage. The

dual task approach was first applied to hemispheric lateralization research in a study where subjects balanced dowels on one finger of either their right or left hands while repeating a previously heard sentence (Kinsbourne & Cook, 1971). The result was a detriment to right hand performance and an enhancement of left hand performance. This outcome and subsequent results of concurrent task studies have been considered by some researchers in terms of models of cerebral hemispheric processing. However, a much larger group of researchers has adopted this paradigm primarily as a method for establishing a hemispheric advantage for a particular cognitive process.

The processing that has been explored with this concurrent approach includes, at least, the following: reading aloud, silent reading, singing, humming, calculating, object naming, manipulospacial processing of block designs, shadowing of American Sign Language, memory encoding of words, objects or numbers, music perception, and mental imaging. It has also been used to compare cerebral hemispheric specialization among differing groups. Studies have been done, comparing males and females, ASL-English bi-linguals, English only communicators and ASL only communicators, left and right handers, monolingual and bilingual individuals, stutterers and non-stutterers, expert and non-expert musicians and children of all ages, for the

purposes of discerning developmental processes in the formation of hemispheric specialization. Both of these lists could be much longer. The research which utilizes this paradigm is extensive, particularly dating from the 70's and 80's. As is true with concurrent task situations in general, the majority of lateralized dual task studies result in a detriment to performance on the output motor task (Kinsbourne & Hiscock, 1983).

In a simplified way, the logic behind this literature is that the hemisphere controlling the hand for which the motor task shows the greatest performance decline in the concurrent situation is also the hemisphere specialized for the primary cognitive processing under investigation. Consistent with this, it is very common for such studies to include two main conditions, fingertapping (or some other output motor task) by itself and fingertapping in combination with the primary task. It is not uncommon for such studies to lack a control condition of performance on the cognitive task alone (Green & Vaid, 1986; Kinsbourne & Hiscock, 1983). This limits the study of the concurrence to a uni-directional view, the effect of the cognitive processing on the motor output. When designed in this way, the performance effects of the motor output task on the cognitive processing will not be revealed.

In addition to this limitation, implicit in the use of the concurrent task paradigm as just described, is a somewhat static view of the nature of hemispheric specialization. The approach is dynamic enough to embrace the idea that motor performance will be altered by other processing. While expecting this possibility, however, it is static in its expectations of any qualitative effect. It seems to assume that the cognitive processing which is being explored will manifest itself, qualitatively, in the same way when performed alone as when performed concurrently with other processing. It assumes that the processing will exhibit the same pattern of hemispheric lateralization. This type of approach is not conducive to revealing alterations in hemispheric advantage due to concurrent information processing, or more typically, by the concurrent motor task.

In a handful of studies, face recognition and lateralization have been explored using the concurrent task paradigm in the manner described above. These studies are summarized by Hiscock (1988). In all of these studies, and in one completed subsequent to that time (Wilcox & Kraft, 1989), face encoding, i.e. presentation of faces to be memorized, occurs simultaneously with fingertapping. A face recognition task follows. In a study by McFarland & Ashton face encoding produced greater interference in left hand

performance. In one by Bowers, Heilman, Satz and Altman and in the study by Wilcox & Kraft, there was equal detriment to both hands. The Wilcox & Kraft work included a control condition to establish baseline performance on the face encoding task alone and thus revealed a greater detriment to the face encoding task in the presence of left handed tapping. While two of the three adult studies utilizing this technique indicate more right than left hemisphere involvement in face encoding, two studies among children indicate an opposite effect.

Despite the different findings among these studies, they share a primary interest in establishing a right or left hemisphere superiority for facial encoding. In this way they differ from the current dissertation which is more concerned with the dynamics of information processing between the hemispheres. In addition, the particular processing concurrence that they explore, face encoding and fingertapping, does not share the ecological relevance of the face and speech processing concurrence looked at in the current studies. Lastly, they are dissimilar to this research in that they involve a concurrence at a different stage of information processing. If information processing is heuristically divided into an input, a processing/storage and an output stage, these studies primarily involve an input-output concurrence; whereas; the current studies

involve an input-input one, in that a face was presented simultaneously with a single spoken word. This was followed by a face recognition task, but no further speech. Despite their lack of direct relevance to the current research, given the paucity of research of this type, it still seemed necessary to at least briefly describe them.

Using a different approach, Klein, Moscovitch, and Vigna (1976) studied face processing in a concurrent task paradigm which did not involve fingertapping. In this case, one face and one written word at a time were simultaneously presented in a lateralized fashion one above the other. Subjects then had to repeat the words they had read and to choose, by manually pointing, the faces they had seen. Allocation of attention was manipulated instructionally across groups to emphasize either the face recognition or the verbal task. Order of performing the tasks was likewise manipulated. Of interest to these researchers was whether hemispheric advantage could be altered by manipulation of attentional bias. This study differs from the current research in that it deals with a unimodal rather than a multimodal concurrence and includes two tasks rather than one task concurrent with passively present secondary stimuli. Despite these differences, it seems more closely related to the approach of the current work than anything else found throughout the literature.

The results of this study indicated that manipulating the task that was given priority could result in alterations in patterns of hemispheric advantage. Subjects who were instructed to attend to the words continued to show the right visual field/left hemisphere advantage shown in the single task situation, but they lost a previously exhibited left visual field/right hemisphere advantage for faces. However, the group attending more to faces continued to display the characteristic advantages previously exhibited for both faces and words. The authors interpret the results from the group that was giving priority to the words as supporting an attentional model of hemispheric lateralization in that the subjects could be directed to shift attention away from the faces with the concomitant loss of the right hemisphere advantage for face processing. Whereas, the results from the group prioritizing face processing were interpreted as supporting a relative access model of cerebral hemispheric processing. Despite the directions to shift attention to the faces, the verbal processing still manifested the characteristic right visual field/left hemisphere advantage presumably brought about by the effect of the required interhemispheric transmission.

In another study involving faces (Umiltà, Rizzolatti, Anzola, Luppino & Porro, 1985), primary tasks of speeded discrimination of words or faces were compared in a single

task situation and a situation where they were performed in conjunction with lateralized output motor tasks. This study was aimed at producing alterations in hemispheric advantage that would help elucidate the strength of alternate models which attempt to explain differential performance between the hemispheres. A left hemisphere advantage for words was maintained in the presence of the motor task, but a right hemisphere advantage for faces disappeared in the presence of the additional task when the motor task was controlled by the right hemisphere. This result has been interpreted as supporting a model of hemispheric advantage based upon interhemispheric transmission time (relative access model). While dissimilar in many ways from the Klein, et. al study described previously, because of the type of concurrence involved, the studies share one similarity. In both cases, in the presence of concurrent activity, the right hemisphere advantage for face processing seems somewhat more fragile than the left hemisphere advantage for verbal processing.

As is evident from this review, hemispheric lateralization research examining simultaneous face and auditory processing is uncommon. The last two studies discussed indicate, however, that there is a precedent for expecting alterations in patterns of hemispheric advantage for face processing to occur based upon concurrent events. Research including the passive presence of auditory

stimulation concurrent with lateralized face processing, as was carried out in the current dissertation, seems to be non-existent. In fact, although this type of concurrence, i.e. multimodal stimulation in a single task situation is common in the non-lateralization literature, it seems to be very uncommon in the lateralization literature as a whole. One of the few studies found using this approach viewed the effect of passively present tactile noise, in the form of unstructured shapes and textures, on a lateralized tactile task requiring similarity judgments on stimuli of different shapes and textures (Cohen & Levy, 1988). The effect of this concurrence was improved performance in the presence of contralateral tactile noise for the right hemisphere controlled left hand only. The authors interpreted this finding as an indication that competing stimulation can modulate patterns of hemispheric lateralization and, more specifically, that in the absence of tactile noise there is normally unidirectional left hemisphere inhibition being exerted over right hemisphere tactile processing.

Another study, somewhat similar in terms of methodology except that it dealt with a multimodal situation, examined the effects of music (continuously played binaurally, monaurally to the right ear, or monaurally to the left ear) on tactual maze solution (McFarland & Kennison, 1988). This study indicated that music primarily directed to the

hemisphere controlling the hand that was solving the maze impeded maze learning, but music directed to the opposite hemisphere facilitated it.

As the preceding summary illustrates, the main reflection of considerations of concurrence in the lateralization literature has been in techniques for establishing hemispheric advantage. However, there are some researchers who have been concerned with the more theoretical issues raised by such studies. Primary among these is Marcel Kinsbourne, one of the originators of the application of the dual task paradigm to hemispheric lateralization research. Beginning with his previously described study of dowel balancing with simultaneous recitation, the observed results were multifaceted. Performance in the left hemisphere controlled right hand was impeded, as one might have expected, but performance in the right hemisphere controlled left hand simultaneously improved. The decrease in performance by the right hand was attributed to intra-hemisphere interference. Enhancement of left hemisphere performance was less convincingly explained. The researchers posited that for a practiced task, which the dowel balancing had become, sufficient distraction to avoid undesirable self-consciousness could improve performance as long as it remained minimal enough to avoid interference (Kinsbourne & Cook, 1971).

Kinsbourne later developed a theory of brain organization that more specifically explained the interference that was observed during such concurrent processing. His theory is a specific form of the multiple resource pool approach (Posner, 1982). It conceptualizes the human brain as a series of neural networks. Cerebral specialization is viewed as being the result of the activity of local networks containing neurons which fire in particular spatial and temporal patterns (Kinsbourne, 1982). Activation can spread from one network to another. Crucial to this theory's explanation of concurrence effects is the concept of functional cerebral distance. Functional cerebral distance refers to the interconnectedness of particular networks. Thus, for example, even though right hand movements are no more closely related conceptually to speech than left hand movements, due to the interconnectedness of the networks controlling each, both being controlled in the left hemisphere, they are more closely related in terms of functional cerebral distance (Kinsbourne & Byrd, 1985). To the degree that concurrent processes, including concurrent tasks, require neural networks which are functionally close, the concurrence will more likely result in interference effects since activation is more likely to spread to these closer networks. Therefore, a particular pattern of activation and the

processing connected to it will more likely be disrupted by a pattern of another simultaneous activity controlled by a nearby network. In this way, functional cerebral distance becomes the critical factor in predicting interference.

According to Kinsbourne, cerebral lateralization produces neural distance since processing that occurs in opposite hemispheres is processing that is functionally distant. Therefore, information processing in opposite hemispheres is processing that can co-occur more readily than processing within the same hemisphere. This should allow for different, perhaps complementary, aspects of the same information processing task to be effectively carried out in parallel. In this way, Kinsbourne's model produces an alternative to the very common dichotomous thinking concerning hemispheric specialization (Kinsbourne, 1982).

The concept of functional cerebral distance is presented by Kinsbourne as part of a general theory of concurrent processing. The definition of functional cerebral distance as the interconnectedness of various neural networks is also general. However, Kinsbourne does not seem to define a basis for determining functional cerebral distance other than the functional cerebral distance resulting from the division into left and right hemispheres. In addition to this, the behavioral studies used to support his concept are primarily concurrent task

studies within the context of hemispheric lateralization. Since functional cerebral distance is supposed to explain why particular processes are more likely to interfere with one another, clearly it would be circular to define functional cerebral distance based upon the magnitude of interference effects. Thus, in the absence of any other operational definition of this concept, Kinsbourne's theory seems to become restricted to a discussion of concurrent processing in relation to the cerebral hemispheres.

While concurrent activity is more likely to lead to interference when it involves functionally proximate neural networks, according to Kinsbourne, sequential activity of functionally proximate networks is more likely to result in facilitation. Kinsbourne has referred to this type of facilitation as priming. This effect is related to a general theory of attention known as the activation-orienting or selective attention hypothesis (Kinsbourne, 1975; Reuter-Lorenz, Kinsbourne & Moscovitch, 1990) which proposes that attention, especially spatial attention, is more likely to shift in the direction opposite the hemisphere which is more activated.

The theoretical distinction between priming, brought about by the sequential activation of closely related neural networks, and of interference, brought about by concurrent activity of closely related neural networks, has been

related to the effects of timing. Information processing which can result in a priming effect ought logically to precede the processing being primed and information processing which can result in an interference effect ought to coincide with the processing being impeded (Kinsbourne & Byrd, 1985). This theoretical distinction is, unfortunately, not consistently borne out experimentally. In the concurrent task situation, certain tasks which precede others sometimes result in interference. Likewise, just as in Kinsbourne and Cook's first concurrent task study, concurrent tasks sometimes facilitate processing in a particular hemisphere. Thus the only reliable distinction between priming and interference is often the post hoc one based upon performance. This is similar to the situation in the non-lateralized study of concurrent processing that was discussed in the very beginning of this section where concurrent processing is determined, post hoc, to have involved interference if performance declines, but facilitation if performance improves.

In a concurrent task study of visual shape recognition with prior verbal encoding and simultaneous verbal memory load, the relationship between priming and interference was explored (Kinsbourne & Byrd, 1985). Priming and interference were both manifested and were found to vary in relation to task difficulty and age of the subjects. Within

the condition of light verbal load, there was selective priming of a right visual field/left hemisphere advantage for shape recognition, but only for young subjects. With increased verbal load, there was bilateral interference for these same young subjects. Elderly subjects did not show priming effects at all. They did manifest a left visual field/right hemisphere interference effect for the shape recognition even in the light verbal load situation. These findings were incorporated into the concept of functional cerebral distance based upon the idea that the degree of activation of "cerebral space" is dependent on the work load. Elderly subjects utilize more functional space for any task and are thus more likely to experience interference even at lighter work loads.

Although this dissertation is not directly raising the questions of divided attention and resource sharing, these issues clearly arise in Kinsbourne's theorizing. And these issues are, to some extent, unavoidably related to the current research. Therefore, before completing the Background section, it seems appropriate to include a brief description of the work of Martha Polson and Alinda Friedman who, along with Kinsbourne, stand out among the theoreticians involved in concurrent task lateralization research.

Initially Friedman and Polson applied theoretical approaches from cognitive psychology to concurrent processing within lateralization research, particularly in relation to dual task issues (Friedman & Polson, 1981). Their emphasis later changed and their explanations of lateralized concurrent task performance were extended to become a general theory to explain all concurrent task performance (Polson & Friedman, 1988). Like Kinsbourne's, their approach is basically a variation of a multiple resources model. For Polson and Friedman, there are two main resource pools. These resource pools are defined by the cerebral hemispheres. Whether or not performing two tasks will result in concurrence costs can be better predicted, for Polson and Friedman, by which hemisphere is involved in the processing, than by any other factor, including sensory modality, similarity of processing or output mode.

In their view, the resources within each hemisphere are limited and cannot be made available to processing in the other hemisphere. However, these resources are not characterized by any of the typical dichotomies used to differentiate the specializations between the hemispheres, such as, verbal/visuo-spatial, sequential/parallel or analytic/holistic (Polson & Friedman, 1988). In the earlier description of their theory, Friedman and Polson describe

the resources of each hemisphere as "qualitatively different from those of the other hemisphere" (Friedman & Polson, 1981, p. 635). Whereas in their later work, the resources of the hemispheres are described as "undifferentiated" (Friedman & Polson, 1988, p. 1040). While there seems to be a lack of clarity in what distinguishes the resource pools, what is clear is that Friedman and Polson think that both hemispheres are able to perform most of the same tasks. They seem to believe that the determination of which hemisphere will perform a particular task must be made empirically, specifically utilizing a task emphasis manipulation.

Both tasks must first be tested individually, then in combination, but with alterations in which task is emphasized. If differing the reward for performing better on one task versus the other results in trade offs in performance, it can be inferred that the processing involved required the same resource pool. This is contrasted with an overall decline in performance in the dual versus the single task situation which does not respond differentially to a task emphasis manipulation. An effect which is not sensitive to a task emphasis manipulation is thought to be the result of a concurrence cost, an administrative type cost of simply keeping track of processing, rather than a

decrement in performance resulting from a specific requirement for the same resource.

Even though, Polson and Friedman differentiate their approach from Kinsbourne's, a number of similarities exist. While Kinsbourne theoretically allows for many resource pools in the existence of multiple neural networks, operationally, he clearly distinguishes only two, the left and right cerebral hemispheres. Also, consistent with Polson and Friedman, he believes both cerebral hemispheres are capable of performing most processing, albeit with differing degrees of efficiency. Kinsbourne's theorizing is broader in that it attempts to account for facilitation as well as concurrence costs; whereas, Friedman and Polson do not move into this domain. On the other hand, Friedman and Polson offer a more defined methodology in their proposal for task emphasis manipulations and they present a more fine tuned view of resource theory in their distinctions between simple concurrence costs versus actual use of the same resource pool.

The above discussion completes the description of the background for the current dissertation. What should be clear from this discussion is the appropriateness of having carried out descriptive studies of the concurrent processing of faces and speech in relation to hemispheric lateralization. Although an interest in this issue has much

general precedent, there is little specific precedent. Therefore, a series of descriptive studies seemed to be a reasonable starting point.

Given that no specific hypotheses were being proposed and that the primary goal of these studies was descriptive, the statistical analyses performed were more extensive, and in some cases slightly less orthodox, than might have been undertaken for a series of studies aimed at disproving specific hypotheses. A search was being made for relationships and suggestive patterns that might provide the basis for future, more specific, questions and hypotheses. Extensive statistical analysis of the kind made here was considered appropriate for this purpose despite the somewhat increased risk of Type I errors.

CHAPTER 2
WHAT IS THE RELATIONSHIP BETWEEN THE HEMISPHERES FOR
PROCESSING FACES IN THE ABSENCE OF SPEECH?

STUDY 1 - FACE RECOGNITION NO SPEECH

INTRODUCTION

The main purpose of undertaking this study was to provide the baseline against which the concurrent processing of faces and speech could be compared.

METHOD

SUBJECTS

The subjects were 25 right handed males and females (18 females and 7 males) with self reported normal hearing. The mean age of 20 of the subjects was 24.8 (SD=6.03) years. There were 5 additional subjects who were within the age range, but for whom the precise age was not ascertained. Subjects were limited to the age range of 16 to 39 due to the visual problems of presbyopia which commonly develop after age 40. Subjects were primarily recruited from undergraduate psychology classes at Hunter College of the

City University of New York. Handedness was assessed using the Bryden shortened handedness questionnaire (Bryden, 1977). Visual screening was performed using a Snellen chart. Subjects with more than 2 errors on the line for 20/20 vision were excluded. The data from 3 of the original 28 subjects were dropped due to anticipatory keying responses.

VISUAL STIMULI

The target faces were images of four males. The choice faces were images of the same four males, but in somewhat different poses (Figure 1). Some researchers studying face perception have questioned whether using identical photographs as targets and choices truly engages face processing or whether it limits the cognitive process under study to a more narrow form of stimulus matching. Even though it has been argued convincingly that matching identical photographs of faces invokes face processing strategies (Sergent, 1989), the concern of this research with ecologically relevant situations led to the more conservative choice of using different views of the same faces for targets and choices.

Originally, the faces were black and white glossy photos that were selected from among hundreds in the

photographic archive of a high school yearbook. Different sets of eight photos (four targets and four choices for each set) were chosen based upon relative similarity among the members of a set. These were narrowed down to one set of four females and one of four males. They were then scanned into a Gateway 2000 486/33 as 256 grey level images with a Hewlett Packard Scanning Gallery Plus 5.0 optical scanner and SCANGAL 5 software. (The sharpness and amount of variation in tone on the computer screen was far superior to that represented in Figure 1. Figure 1 faces are the product of photocopying half tone prints that were produced by a laser printer and SCANGAL 5 software.) Modifications, including cropping, adjustments to brightness levels and occasional creation of a mirror image, were made with SCANGAL5 software. The graphics files were stored in PCX format and passed to a program written in TURBO PASCAL 6.0 (Bruce Williams, 1993). This program converted the files into a format usable by the presentation program (Bruce Williams, 1994). The faces were presented as 2.5 cm. wide by 3.5 cm. high black and white images on a black background. Preliminary computer presentation of the two sets of faces to students registered in experimental psychology indicated that the set of males was quite similar and yielded error rates necessary for analysis of errors and this set of faces was used in all subsequent studies.

APPARATUS

The experiment was run on a Gateway 2000 486/33 with VGA graphics. The keyboard was a Gateway 2000 and the CRT was a Gateway 2000 Crystal Scan 1024 NI with a 640 X 480 pixel configuration. Subjects wore SONY Digital reference MDR CD350 headphones.

PROCEDURE

The subjects performed a delayed face recognition task. A single lateralized target face was presented. It was followed by four faces from which the subject was to choose the face of the person whose face was the target. Subjects were seated 60 cm from the screen with their chin in a chinrest. The target faces were presented 5 cm. to the right or to the left of the center of the screen. The combination of seating distance from the screen and presentation distance from the center of the screen resulted in a visual angle from fixation to the center of the stimuli of 6.0 degrees.

Subjects were given verbal instructions which approximately followed a written script (See Appendix B.) Figure 2 portrays the sequence of events for each trial. Each trial began with the appearance of a flashing white

fixation circle at the center of the screen. The circle had a diameter of 6mm and flashed on the screen for 2 seconds. In the directions given subjects prior to the beginning of the session, subjects were told that it was critically important for them to look directly at the fixation circle whenever it appeared.

Immediately after the fixation circle was removed from the screen, the target stimulus was presented for 65 msec. Then there was a 2 second delay between the target and the choice. The choice faces were the same size as the targets and were presented in a diamond array. The position of a particular face in the array was randomly determined each time the array was presented. Subjects indicated their choice from the array by pressing the corresponding key from the bank of arrow keys on the keyboard (Figure 2). They did this with the index finger of their left hands. The keyboard was positioned with the arrow keys at approximately midline. Entering a response triggered the next presentation of the fixation circle.

While fixation is sometimes monitored by using video recordings or by requiring subjects to report a centrally presented digit, very often it is controlled with instructions, as was done here. It has been found experimentally that almost all normal subjects correctly maintain fixation as they are instructed to do (Moscovitch,

1986). Furthermore, there is evidence indicating that the occurrence of eye movements is minimal. Eye movements were electronically monitored in a study which used a much longer presentation time, viz. 180 msec. In this case, it was found that fewer than 2% of the trials included eye movements and that those few that did occur were not systematically related to any of the groups or conditions under study (Hugdahl, et al., 1993).

The face recognition session was divided into 6 blocks of 24 presentations each. Within a block, each face was presented 3 times to each visual field. Each face was thus presented 36 times as a target and 144 times (altered view) in the choice array. Blocks 1, 3 and 5 were uniquely randomized for each subject. Blocks 2, 4 and 6 were mirror images of the preceding blocks in that the randomization order was the same, but each face was presented in the opposite visual field. After each block of 24 trials, a message appeared on the screen which said to press enter to continue. Subjects had been told that they could take a moment to rest at this point if it was needed. Sessions varied in length due to the fact that subjects' responses triggered presentations of the next trials, but the typical duration was 30-45 minutes. During the entire session, the experimenter remained in the room, seated behind the subject, to detect any problems that might occur.

FIGURE 1
STUDY 1
FACE STIMULI

TARGET



CHOICE



TARGET



CHOICE



TARGET



CHOICE



TARGET

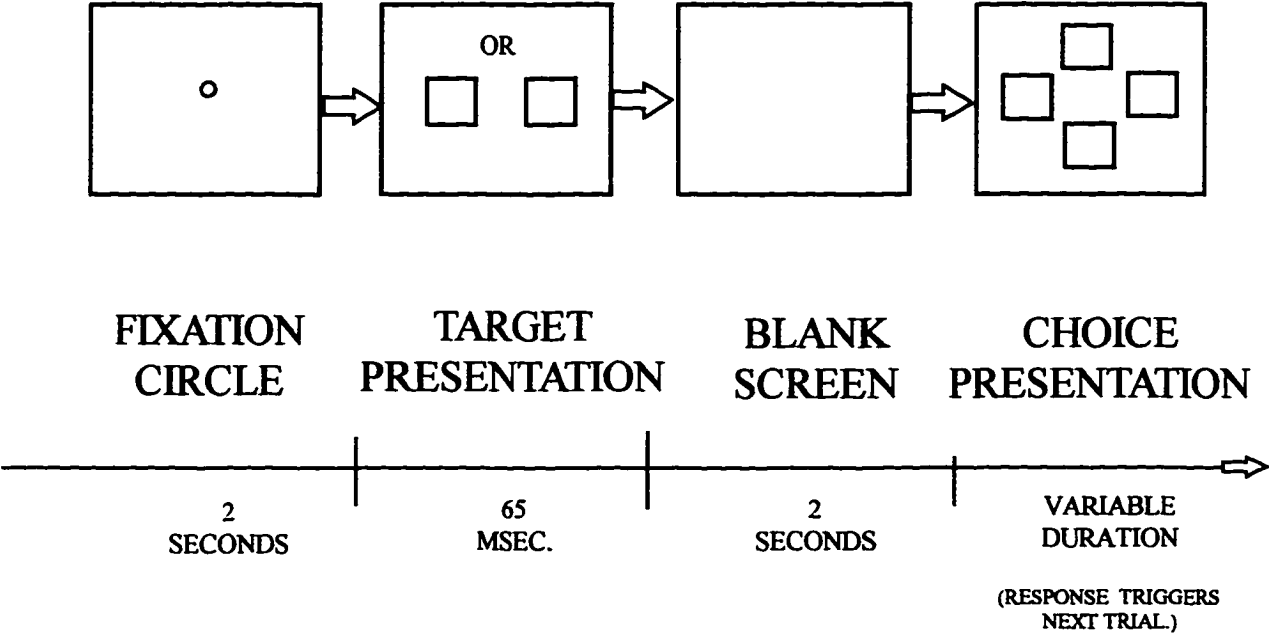


CHOICE



FIGURE 2

FACE RECOGNITION
SINGLE TRIAL TIME LINE



STUDY 1
RESULTS
ACCURACY AND REACTION TIMES IN LVF AND RVF ON FACE
RECOGNITION

ACCURACY

Statistical analyses for all of the studies were completed using SPSS/PC (for DOS) version 5.2. The mean number correct for the faces was 69.0 (SD=19.0) out of 144, an overall correctness score of 47.9% which is well above the 25% level expected by chance. Subjects got a mean of 34.4 (SD=9.7) faces correct in the left visual field (LVF) and 34.6 (SD=11.5) faces correct in the right visual field (RVF). Thus, there was no difference in accuracy between the visual fields ($F(1,24)=.02$, $p=.89$), as shown by an ANOVA, with repeated measures on visual field.

The effect of block was also examined. Since the same set of faces were presented repeatedly, it was reasonable to expect that performance would improve across time. The percent correct increased from 37.5% in Block 1 to 52.1% by Block 6. This is reflected in a significant block effect ($F(5,120)=9.11$, $p<.001$) and a significant linear ($t=4.44$; $p<.001$) trend. However, there was no difference between the visual fields in this process as indicated by the lack of a visual field by block interaction ($F(5,120)=1.07$, $p=.39$). (Raw data by block are reported in Appendix A, Table A2.)

REACTION TIME/SPEED

Most hemispheric laterality studies have used either speed or accuracy, but not both, as dependent measures. When accuracy is used the task is normally designed to be difficult enough to produce high error levels (around 50%). On the other hand, when speed is used, the task is often designed to produce very high correctness levels. Since this study used both measures, the correctness level is not very high. It is therefore necessary to confine assessment of processing speed to mean correct reaction times only. It would be misleading to consider faster processing speed in a particular visual field as an advantage if the faster responses include large numbers of incorrect choices.

Levene tests for homogeneity of variance revealed that the total mean correct reaction time measures for left and right visual fields did not have homogeneous variances and thus violated the assumptions of the ANOVA. Therefore, a reciprocal square root transformation was applied (Norusis, 1993). After the transformation was applied, Levene tests were redone and the data then met the required assumptions. (See Appendix A Table A1 for analysis based upon non-transformed measures.) All inferential statistics for

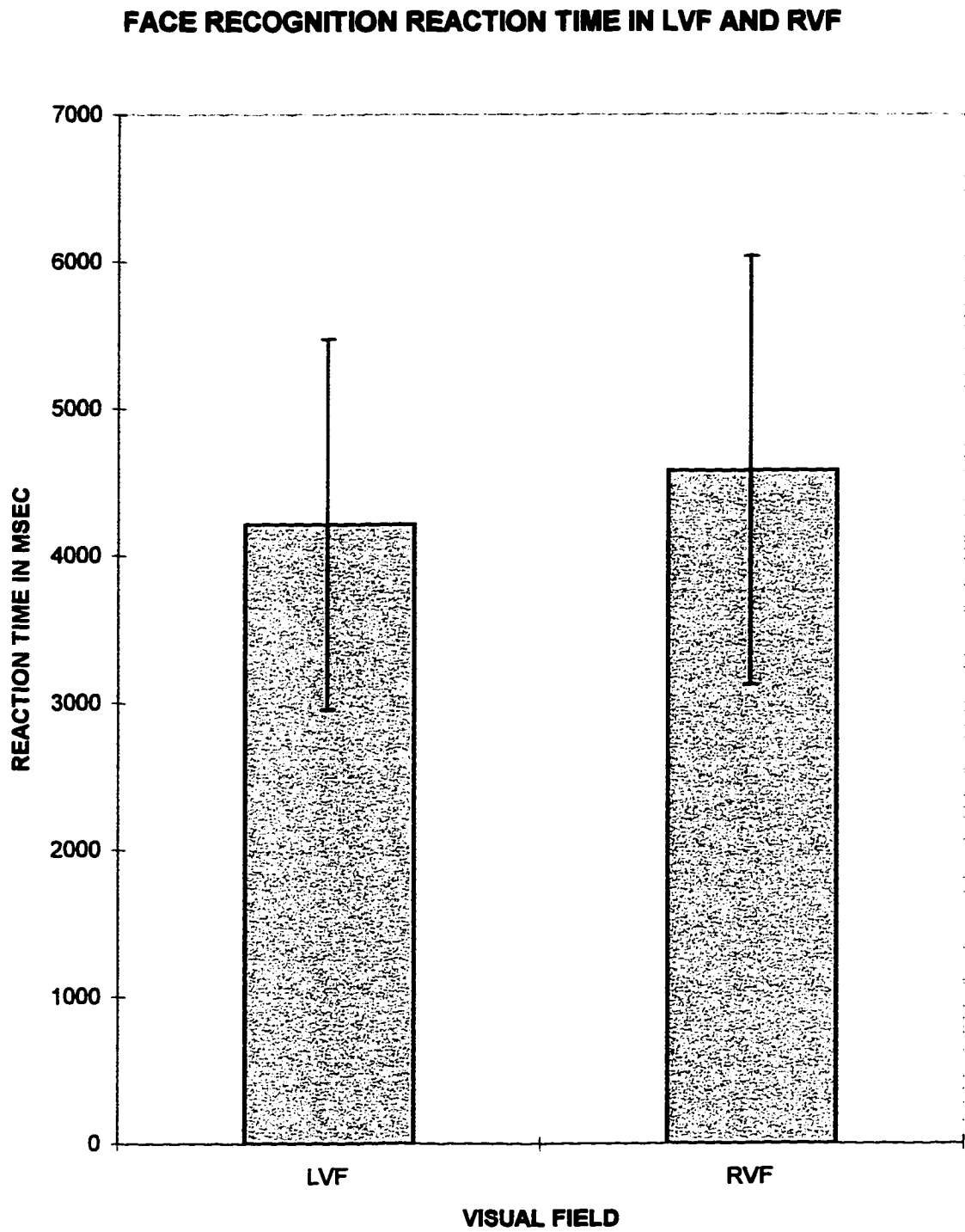
reaction times were done on transformed data, but reaction times reported in tables are raw data.

The mean reaction time per correct response was 4396 msec (SD=1294). The mean reaction time for correct responses in the LVF was 4213 msec (SD=1260) and in the RVF was 4579 msec (SD=1458). This 366 msec difference between the LVF and the RVF responses was significant based upon a repeated measures ANOVA ($F(1,24)=4.56$, $p<.05$). Thus, the LVF responses were faster than the RVF responses. See Figure 3.

In order to examine whether this faster LVF response was a general one, perhaps due to a factor such as responding hand, the reaction times for the incorrect responses were also examined. The reaction times for incorrect responses were subjected to the same transformation as the correct ones. Subjects had a mean reaction time for incorrect responses in the LVF of 5002 msec (SD=1538) and a mean reaction time for incorrect responses in the RVF of 5124 msec (SD=1469). While the LVF was 122 msec faster than the RVF, this difference was not significant ($F(1,24)=1.08$, $p=.31$). This eliminates the idea that incorrect responses reflect any lateralized response. As would be expected, the mean correct responses were significantly faster than the incorrect ones ($F(1,24)=16.08$, $P<.001$).

A two by six repeated measure ANOVA was used to examine the decrease in reaction time across blocks. It was found that this decrease was significant ($F(5,120)=8.82$, $p<.001$). There was also a significant linear trend ($t=3.78$; $p<.001$). Thus, subjects became both more accurate and faster with practice. However, as with the number correct, there was no block by visual field interaction ($F(5,120)=1.12$, $p=.36$). (Reaction time by Block data are reported in Appendix A, Table A3 and incorrect reaction times are reported in Table A4.)

Figure 3
Study 1



STUDY 1
RESULTS
RELATIONSHIP BETWEEN SPEED AND ACCURACY ON FACE RECOGNITION

As previously discussed, this study differs from most studies of hemispheric lateralization in having both speed and accuracy measures available from which to make inferences about hemispheric advantage. Correlations were calculated between total faces correct, the accuracy measure, and mean correct reaction times, the speed measure.

It was felt that a negative correlation, i.e. faster and more accurate or slower and less accurate (e.g. low reaction time and high number correct or high reaction time and low number correct), might suggest a complementary process - either highly efficient or highly inefficient. On the other hand, a positive correlation, faster but less accurate, or slower but more accurate, might be indicative of some sort of trade off in processing. For correct responses, greater speed is associated with greater accuracy as indicated by a negative correlation between mean reaction time in msec and total number of faces identified. This correlation does not reach significance ($r(25) = -.31$, $p = .13$); however, the relationship between speed in the RVF and overall accuracy does reach significance ($r(25) = -.43$, $p < .03$) - the faster the RVF correct responses, the greater the total number of faces correct.

Looking at the relationship between speed and accuracy within and between the hemispheres, two effects are of note. There is a relationship between speed and accuracy within the RVF such that faster correct responses are associated with greater accuracy. This is indicated by the negative correlation (remember, a higher reaction time indicates a slower response) between mean reaction time of RVF correct responses and number correct in the RVF ($r(25) = -.52, p < .01$). On the other hand, there is no relationship between speed and accuracy within the LVF ($r(25) = .02, p > .05$). Not only is there no relationship between LVF reaction time and LVF number correct, but when the RVF and LVF correlations are compared directly, utilizing a test for the difference between two dependent correlations (Bruning & Kintz, 1977), they are found to be significantly different from one another ($t = 4.76; p < .001$). Thus, the RVF performance based upon speed and accuracy coincides - the faster the better - while there is no evidence that the LVF performance does.

Substantial individual variability in relation to hemispheric lateralization has been observed (Levine, et al. (1984) and Ross & Turkewitz, (1981) e.g.). Thus, it was felt that a division of subjects based upon visual field processing speed advantage might be useful in further understanding the relationship between speed and accuracy and the data in general. Subjects were divided based upon

the reaction time differences between correct responses to faces in the LVF and correct responses to faces in the RVF. See Table 1 for a summary of these data. Such a division of subjects resulted in 6 subjects who were faster in the RVF and 19 subjects who were faster in the LVF for correct responses. Based upon a Chi Square analysis, this difference was shown to be significant ($\chi^2=6.76$, $df=1$, $p<.01$) Thus, when faces are processed without speech, a greater number of individuals respond more quickly in the LVF than in the right. This is consistent with the observation that the LVF reaction time was significantly faster than the right. However, the handful of individuals who do perform faster in the RVF, also perform better overall. They recognized a mean of 82.3 faces correctly while the LVF group recognized a mean of 64.8 faces correctly. This difference of 17.5 faces, (12.3 more faces correct in the RVF and 5.2 more faces correct in the LVF) is just significant ($F(1,23)= 4.17$, $p=.05$). See Figure 4. This finding seems consistent with the positive correlation between speed and accuracy in the RVF (which is expressed in the negative correlation between reaction time and accuracy).

There was a non-significant trend for each group to be faster and to get more faces correct in the same visual field (LVF ADV: LVF 33.1 and RVF: 31.7; RVF ADV: RVF 44.0 and LVF: 38.3). (group by visual field interaction: $F(1,23)=3.52$, $p<.08$).

TABLE 1
STUDY 1

INDIVIDUALS GROUPED BY PROCESSING SPEED ADVANTAGE
FASTER IN LVF (LVF ADV) VERSUS FASTER IN RVF (RVF ADV)

ACCURACY IN LVF AND RVF ON FACE RECOGNITION
NUMBER OF FACES CORRECTLY RECOGNIZED

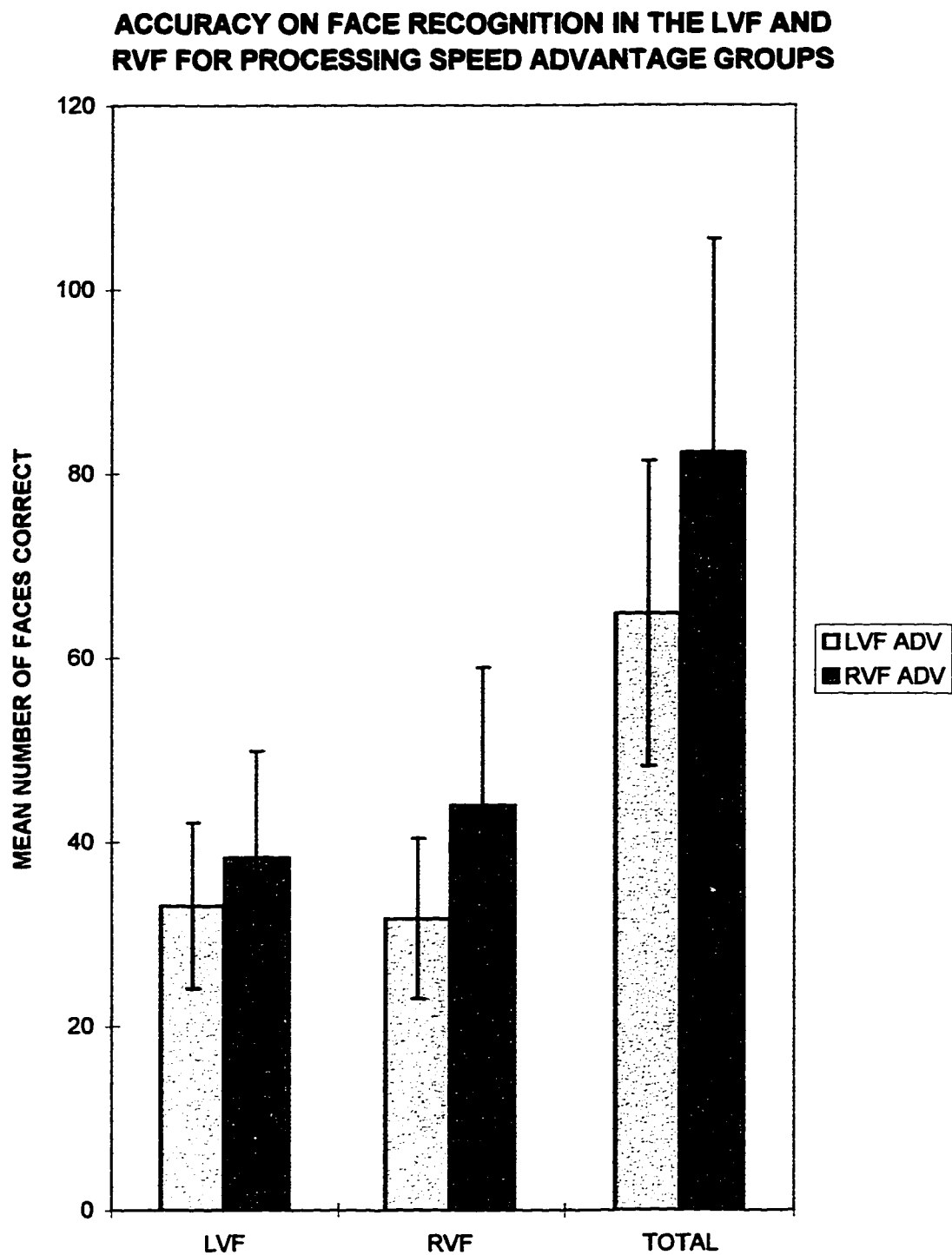
	<u>N</u>	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
LVF ADV	19	33.1	(9.0)	31.7	(8.7)	64.8	(16.6)
RVF ADV	6	38.3	(11.6)	44.0	(15.0)	82.3	(23.2)

SPEED IN LVF AND RVF ON FACE RECOGNITION
REACTION TIMES FOR CORRECT RESPONSES

(IN MSEC)

	<u>N</u>	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
LVF ADV	19	4129	(1182)	4731	(1399)	4430	(1224.8)
RVF ADV	6	4476	(1575)	4096	(1670)	4286	(1618.1)

Figure 4
Study 1



STUDY 1
SUMMARY OF OBSERVATIONS

- * RH (LVF) 366 msec faster than LH (RVF), but no evidence for difference in accuracy
($F(1,24)=4.56$, $p<.05$)
- * Speed and accuracy within the LH (RVF) are positively related
reaction time and accuracy: ($r(25)=-.52$, $p<.01$)
- * RH (LVF) speed and accuracy are not, however, related and the correlations between LH (RVF) speed and accuracy and RH (LVF) speed and accuracy are different
($t=4.76$, $p<.001$).
- * More subjects are faster in RH (LVF) than in LH (RVF)
($p<.02$)
- * Those (6 of 25) who are faster in LH (RVF) recognize 17.5 more faces correctly overall
($F(1,23)=4.17$, $p=.05$)

STUDY 1
FACE RECOGNITION NO SPEECH
DISCUSSION

In the study of face processing without speech, one of the main observations is that right handed individuals respond more quickly to faces when they are presented to the LVF/right hemisphere (RH) than when presented to the RVF/left hemisphere (LH). Their response is 366 msec - more than a third of a second - faster in the LVF (RH) than in the RVF (LH), but there is no evidence that responses in one visual field are more accurate than responses in the other.

As stated previously, few lateralization studies examine both accuracy and speed within the same paradigm. One exception is a study of the perception of facial expression in relation to gender. In this case, there was a consistent right hemisphere advantage based both upon speed and accuracy (Hugdahl, et al., 1993). It is interesting that in the current study processing was observed for which there was a particular hemispheric advantage in terms of reaction time but not in terms of number correct. What is the meaning of a hemispheric advantage that involves being faster without being more accurate? In studies which have only used reaction time, being faster has always implicitly been equated with being better. But when both measures are

available and it is known that being faster is only that, the interpretation of the phenomenon is a little more difficult. Is it enough to simply say that faster processing speed is a reflection of ease of processing, of being more efficient, but not necessarily of being better at the task? The current study raises such questions of interpretation.

As stated above, the right hemisphere advantage in speed of response is consistent with a large body of literature that associates expertise in face processing with the right hemisphere more than with the left. When the relationship between accuracy and speed is examined in greater detail; however, a more complex picture emerges. While subjects' responses in the RH (LVF) are in general faster, there is a positive correlation between most accurate performance and fastest performance within the LH (RVF), but not within the RH (LVF). Thus, the left hemisphere seems to have a more consistent advantage. Of course, the least accurate performance will also be the slowest; so that, consistency per se is not an advantage unless more LH responses are consistent in the direction of being accurate and fast.

In order to explore this question further and to highlight individual differences in these processes, subjects were divided into groups based upon the relative

speed of their correct responses. Most subjects were found to have responded more quickly in the LVF (RH) than in the RVF (LH). This is consistent with the general observation of faster responses in the RH (LVF) and with the literature that indicates a stronger role for the right hemisphere in face processing. However, the handful of subjects who responded more quickly in the LH (RVF), rather than the RH (LVF), performed better overall and especially in the LH (RVF) (approaching significance). This finding, then, provides the evidence for a consistently fast and accurate, and overall superior mode of LH (RVF) processing, that the correlational data suggested as a possibility. It also convincingly reflects the idea that what is the most typical mode of processing, the one most individuals tend to exhibit (in this case one that is reflected in relatively faster responses in the LVF (RH)), may not be the most proficient for dealing with a particular set of stimuli. There may be a dissociation between what is typical and what is most effective.

It might be the case that the handful of individuals who exhibit this highly efficient LH processing style can more flexibly and easily engage alternate processing strategies, ones that might be especially effective for handling a particular task and a particular set of stimuli and which would result in this atypical processing pattern

in relation to lateralization. At the outset of these studies, the face stimuli were intentionally chosen based upon similarity. One successful approach for distinguishing very similar faces might be to attend to small differences in particular features. Both the processing of similar faces (Sergent, 1983) and the processing of facial features (Ross & Turkewitz, 1981) have been shown to favor processing lateralized to the LH more than to the RH.

It seems appropriate to discuss one last aspect of the observations from Study 1 before concluding this discussion. A possible interpretation that might be offered for the observed difference in reaction time is that it was due to the left hand, controlled by the RH, making the response. According to such a view, the RH would have an advantage in relation to speed of response since there would be no time lost in transmitting the motor output signal to the opposite hemisphere. However, there are two factors which would argue against such an interpretation. A review of a number of hemispheric lateralization studies which measure reaction time reported typical values of 2 msec difference for simple reaction time studies and 100 msec for more complex studies (Moscovitch, 1986). Compared with these differences, the 366 msec difference observed in this study seems large. The difference is of such a magnitude that an explanation involving a RH motor response time advantage due to

responding with the left hand seems unlikely, especially since a single callosal crossing is estimated to take 2-6 msec to complete (Moscovitch, 1986). The second factor mitigating against accepting response hand as an explanation for these differences is that incorrect responses did not show the same pattern of hemispheric advantage as correct responses; although, they too required use of the left hand for the response.

CHAPTER 3

WHAT PROCESSING ALTERATIONS OCCUR WHEN RELATED SPEECH IS PRESENTED CONCURRENTLY WITH FACES?

STUDY 2 - FACE RECOGNITION WITH RELATED SPEECH

INTRODUCTION

The purpose of this study was to examine the effects of concurrent speech input on the face recognition task. More specifically, it was aimed at studying the effects of concurrent related face and speech stimuli on patterns of hemispheric lateralization and subsequent unimodal face recognition.

Ideally, the situation that the current research aimed to describe should have been explored using dynamically changing talking faces. However, the time constraints of lateralized visual presentation (maximum of 250 msec), in combination with technological limitations, precluded this possibility; so that, the actual concurrence involved two simultaneous inputs, a lateralized still face and a binaural speech sound, namely a spoken word. Thus, the studies do not precisely represent the ecologically relevant situation of processing a talking face, processing which sparked the current research. However, this limitation does not necessarily exclude them from the realm of ecological relevance.

Specifically attending to a moving mouth and the synchronous speech sounds being emitted from that mouth is one aspect of the processing of a talking face. Such processing is known to enhance the comprehension of the language aspects of speech (Campbell, 1989). This form of processing is least captured in the current studies. However, apprehending a talking face might also involve dispersed attention and the formation of more general associations between the visual properties of the face and speech. Indeed, we know that such associations are made between an individual's face and his voice so that eventually one can bimodally recognize that individual. It seems highly unlikely that such recognition is based upon the connection between an individual's voice and the unique characteristics of his moving mouth. Thus, this more general association, which is not necessarily so likely to be related to talking per se, is also an ecologically relevant aspect of the processing of a talking face and one that is to a greater extent maintained in the current studies.

STUDY 2 - FACE RECOGNITION WITH RELATED SPEECH

METHOD

SUBJECTS

The subjects in this study were recruited and screened exactly as they were for Study 1. There were 25 right handed males and females (19 females and 6 males) with self reported normal hearing and with a mean age of 23.3 (SD=6.9) years who participated. In this study, the data from 1 additional subject was dropped due to anticipatory keying responses.

AUDITORY STIMULI

The auditory stimuli were binaurally presented voices saying one word at a time. Auditory stimuli were presented simultaneously with faces (Stimulus Onset Asynchrony = 0). Six different words were spoken by each of 4 male speakers; so that, there were 24 unique word/voice combinations. Each voice, with its set of six words, was associated with a particular face as depicted in Figure 5. Each voice was repeated a total of 36 times during the face recognition session, one time for each target presentation of its

related face. Each word/voice combination was repeated 6 times.

Different words were presented by each voice rather than a single word or name per voice to weight the design in the direction of a voice rather than a label or name being associated with a particular face. The decision to emphasize the voice component of the speech signal was based upon the ecologically prevalent situation of face and voice both being used for purposes of identification of individuals.

The words were nouns chosen from Paivio (1966) that had been rated on imagery (I). This rating was found to positively correlate with free recall (Paivio, 1968). The ratings were used to choose groups of words for each voice that were approximately equivalent in imagery rating. The same word list and imagery ratings were also used to select words for the auditory recognition session. Frequencies of the words ranged from 1 to 100 per million.

Voice segments were recorded into a Marantz PMD430 professional portable cassette recorder. They were brought into the Gateway 2000 486/33 at a sampling rate of 22.05 Khz and divided into individual voice files containing one word each for a total of 24 separate files. This was done using Soundblaster Pro software and a Soundblaster Pro soundboard.

The mean duration of the words presented during the face recognition session was 700 msec (SD = 120 msec). Output decibel levels from the headphones were measured using a Bruel & Kjaer Precision Sound Level Meter Type 2203 with a Bruel & Kjaer Octave Filter Set Type 1613. The mean for the 24 target words was 60.6 dB S.P.L. (SD = 1.98 dB S.P.L.). Thus, the words were presented at a conversational volume and were clearly audible. Decibel levels of ambient sound were highest at the lower frequencies (e.g. 62 dB S.P.L. at 63 Hz) and dropped for the higher frequencies (e.g. to 40 dB S.P.L. at 2000 Hz). These voice/word files were accessed and played as needed from the presentation program. Subjects received the auditory input through SONY Digital reference MDR CD350 headphones.

PROCEDURE

The face recognition session for Study 2 was identical to that for Study 1 with one major alteration. Simultaneously with the onset of each target face, one of four male voices speaking one word was presented. The same voice was always presented with the same face. One of six words was also presented with the same face. See Figure 5. Since the mean duration of the words was 700 msec and the target faces were presented for only 65 msec, the speech

sounds continued after the termination of the face and ran into the 2 sec wait period between target and choice as can be seen in Figure 6.

Instructions to the subjects did NOT inform them that they would hear voices. The speech was completely incidental. No attention was intentionally drawn toward it by the experimenter. Obviously, the subjects were also not forewarned about being tested on the speech stimuli. The few subjects who even asked about the headphones were simply told not to be concerned with them.

At the close of the face recognition session the subjects began the auditory recognition session which is described in detail below. When they completed the auditory recognition session, they were given an informal interview which included such questions as whether they thought there was a connection between a voice and a face, whether they thought each face was on the screen for the same amount of time and whether they could remember any of the words that they had heard. (See Appendix B.) This questionnaire had not been used in Study 1, but was used for all subsequent studies.

FIGURE 5
STUDY 2
AUDITORY & FACE STIMULI

VOICE #1

TRUMPET
QUEEN
MUSEUM
GRIEF
MISSILE
JUSTICE

MEAN I VALUE=4.38

TARGETCHOICEVOICE #2

DIAMOND
WEAPON
MONARCH
ROBBERY
WHALE
HEROISM

MEAN I VALUE=4.39

TARGETCHOICEVOICE #3

DOLLAR
AMBULANCE
INSECT
JOKE
MURDER
MOOD

MEAN I VALUE=4.34

TARGETCHOICEVOICE #4

PIANIST
VEHICLE
BEVERAGE
WARMTH
FORM
SENSATION

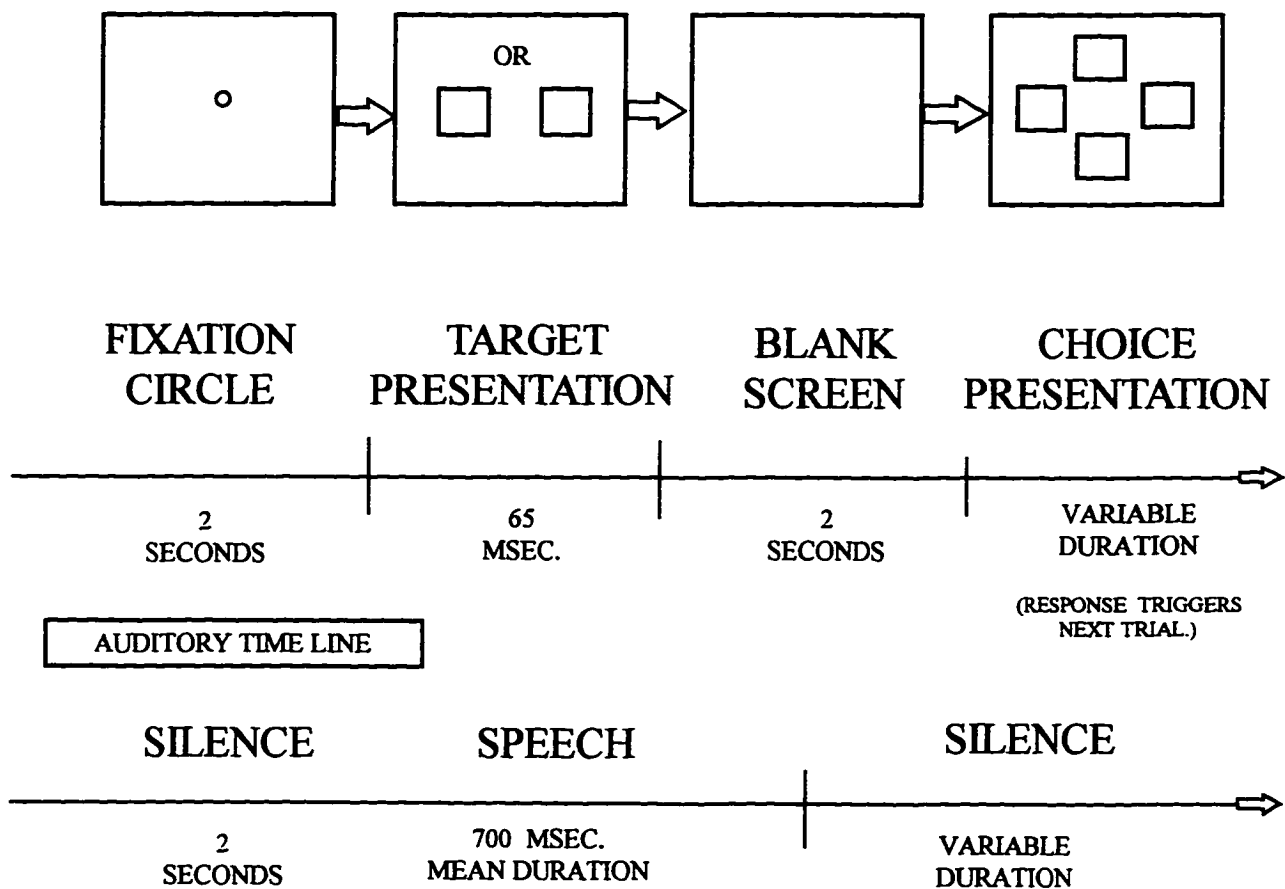
MEAN I VALUE=4.28

TARGETCHOICE

NOTE: Paivio's I(magery) values reflect ease of image arousal.

FIGURE 6

FACE RECOGNITION WITH SPEECH SINGLE TRIAL TIME LINE



STUDY 2
RESULTS
ACCURACY AND REACTION TIMES IN LVF AND RVF ON FACE
RECOGNITION

ACCURACY

A mean of 65.9 (SD=12) faces were correctly recognized. This is an overall correctness level of 45.8% which is well above the 25% chance level. While this is 3.1 fewer faces correctly recognized than in Study 1, when the data were analyzed across Study 1 and Study 2 this difference was found to be non-significant. This was determined using an ANOVA with one between group factor on study and one within group factor on visual field ($F(1,48)=.46$, $p=.51$). As in Study 1, there was no difference in the accuracy between the visual fields ($F(1,24)=.01$, $p=.95$).

The effect of block was also examined and a significant block effect ($F(5,120)=9.02$, $p<.001$) was found, as well as a significant linear trend ($t=4.54$, $p<.001$). Thus, as in the processing of silent faces, the number of faces correctly recognized increased across time. Once again, there was no difference in the performance between the visual fields over time as indicated by the lack of a visual field by block interaction ($F(5,120)=.34$, $p=.89$). (The raw data by block can be found in the Appendix A, Table A5.)

REACTION TIME/SPEED

As with face recognition in the absence of speech (Study 1), a reciprocal square root transformation was applied to the mean total correct reaction time data to correct for lack of homogeneity of the variances. All inferential statistics used the transformed data, but the raw data appear in tables. (Analysis based upon non-transformed measures is in the Appendix A, Table A1.)

The total mean correct reaction time was 4729 msec (SD=1401). The mean correct reaction time in the LVF was 4666 msec (SD=1285) and in the RVF was 4791 msec (SD=1633). This 125 msec difference was not significant based upon a repeated measures ANOVA ($F(1,24)=.07$, $p=.80$). Thus, contrary to Study 1, there is no evidence of a difference in speed between the visual fields. There was also no evidence of a difference in the reaction time between the visual fields for the incorrect responses which were 5796 msec (SD=2126) in the LVF and 5901 msec (SD=2385) in the RVF ($F(1,24)=.05$, $p=.84$). The mean correct responses were significantly faster than the incorrect ones ($F(1,24)=25.95$, $P<.001$).

The mean correct reaction time in the study of face recognition with related speech (Study 2) was 333 msec slower than in the study of face recognition in the absence of speech (Study 1). See Table 2. In order to determine whether this difference was significant, the data were analyzed across studies with an ANOVA including one between group factor on study and one within group factor on visual field. The 333 msec slower response was not significant as indicated by the lack of a main effect of study ($F(1,48)=.98$, $p=.34$). Additionally, this analysis was used to examine whether the faster LVF correct reaction time observed in Study 1 was different from the lack of a faster visual field reaction time observed in Study 2. This analysis did not reveal a significant study by visual field interaction ($F(1,48)=2.63$, $p=.11$). Thus, while one can say that in Study 1 the LVF responses are faster than the RVF responses and in Study 2 this is not the case, one can not say that this difference is statistically significant.

A two by six repeated measure ANOVA was used to examine the decrease in reaction times across blocks. It was found that this decrease was significant ($F(5,120)=6.49$, $p<.001$) and that there was also a significant linear trend ($t=-3.68$, $p<.001$). Once again, subjects became both more accurate and faster with practice. There was no block by visual field interaction ($F(5,120)=.37$, $p=.87$) providing no evidence of a

visual field difference in this process. (Block data are in Appendix A, Table A6 and incorrect reaction times can be found in Table A7.)

Sex was not included as a factor in the main analysis of accuracy or reaction time due to an unavoidably unbalanced female male ratio. However, separate data for females and males can be found in Appendix D.

TABLE 2
 STUDY 1 AND STUDY 2 COMPARED
 FACE RECOGNITION REACTION TIME IN LVF AND RVF
REACTION TIMES FOR CORRECT RESPONSES
 (IN MSEC)

<u>STUDY</u>	<u>N</u>	<u>LVF</u> MEAN SD	<u>RVF</u> MEAN SD	<u>TOTAL</u> MEAN SD
STUDY 1	25	4213 (1260)	4579 (1458)	4396 (1294)
STUDY 2	25	4666 (1285)	4791 (1663)	4729 (1401)

STUDY 2
RESULTS
RELATIONSHIP BETWEEN SPEED AND ACCURACY

Based upon the same rationale discussed for Study 1, the relationship between speed and accuracy was examined and Pearson correlations were calculated. Overall, faster responses are related to greater accuracy; however, these correlations are not significant. In looking at the relationship between speed and accuracy within and between the visual fields, the patterns that emerge in the presence of related speech are different from those that occurred in the absence of speech. The strongest relationship is between speed in the RVF (LH) and accuracy in the opposite visual field - the LVF (RH). This is indicated by a significant negative correlation between reaction time in the RVF (LH) and number correct in the LVF (RH) ($r(25) = -.41$, $p < .04$). However, speed in the LVF (RH) is not related to accuracy in the RVF (LH) ($r(25) = -.12$, $p < .56$) and the difference between these two correlations is significant ($t = 2.07$, $p < .05$), as revealed by a test for the difference between two dependent correlations (Bruning & Kintz, 1977).

For face processing in the presence of speech, then, faster responses in the RVF (LH) appear to be associated with more accurate performance in the LVF (RH). Speed and accuracy are most strongly related across the hemispheres in

only one direction; whereas, for face processing in the absence of speech, speed and accuracy are most strongly related within the RVF (LH).

To further understand the relationship between speed and accuracy and in recognition of individual differences in laterality, an analysis of subjects divided based upon relative processing speed advantage (ADV) was done. This division of subjects resulted in equivalent sized groupings. Twelve subjects were faster in the RVF (LH) and 13 were faster in the LVF (RH) for correct responses. This differs from the processing of faces in the absence of speech (Study 1) where significantly more subjects had a LVF (RH) ADV (19 of the 25 subjects). See Table 3. A Chi Square comparison, between Study 1 and Study 2, of the distribution of subjects in each group failed to reach significance ($\chi^2=3.13$, $df=1$, $p<.08$).

Additionally, there is no longer any evidence that those subjects with a RVF ADV were superior at face recognition as they had been in Study 1. This was determined with a repeated measure ANOVA ($F(1,23)=.17$, $p=.69$). Also, contrary to the findings in Study 1, there was a non-significant trend for subjects to respond to more faces correctly in the visual field opposite the one in which they were faster (group by visual field interaction: $F(1,23)=3.02$, $p<.10$). This provides weak evidence

indicating a tendency for hemispheric advantage based upon accuracy and hemispheric advantage based upon speed to be reversed as was suggested by the previously reported correlations.

The subjects who exhibited a RVF ADV in Study 2 correctly recognized a mean of 12.5 fewer faces in the RVF and 5.0 fewer faces in the LVF than did the RVF ADV group in Study 1. The LVF ADV group in Study 2 did not manifest such a decline in RVF performance. These differences may be reflected in a significant study by hemispheric advantage by left right interaction ($F(1,46)=6.50$, $p<.01$) resulting from a 2 by 2 repeated measures ANOVA. Due to the uneven cell sizes in Study 1, however, this interaction must be viewed with some caution.

These observations suggest that the processing of speech might be disrupting the emergence of a highly efficient RVF ADV processing speed group that is especially accurate in the RVF (LH). The RVF ADV group that does appear in Study 2, does not demonstrate the superior face recognition performance especially in the RVF (LH).

Appropriate to a descriptive study, where one is not aiming to reject or accept a specific hypothesis, but rather to generate possible research questions, another post hoc division of subjects was employed. The aim of this division was to look further into the issue of reversal of accuracy

and speed across the hemispheres that was suggested by the previously described correlation between speed in the RVF (LH) and accuracy in the LVF (RH). Subjects were divided into two groups. One group was relatively faster in one visual field and relatively more accurate in the other - hemispheric advantage based upon speed and accuracy was reversed. The other group had a consistent advantage based upon both speed and accuracy. In Study 2, eight subjects displayed a consistent advantage; whereas, 17 subjects had hemispheric advantage based upon speed and accuracy reversed. Thus, more of the subjects exhibited reversed advantage. In Study 1, the opposite pattern is evident. There, most subjects showed consistent advantage (15 consistent and 8 reversed with 2 subjects falling out of the analysis because they exhibit no advantage based upon numbers of faces correctly recognized). Based upon a Chi square analysis, the distribution of subjects is significantly different between Studies 1 and 2 ($\chi^2=5.30$, $df=1$, $p<.03$). Thus, further evidence is provided for the idea that the concurrent processing of speech with faces tends to result in a more typical face processing style that involves being more accurate in one hemisphere and being faster in the other. This is in contrast with a style of being consistently fast and accurate in the same hemisphere for the processing of silent faces.

TABLE 3
STUDY 1 AND STUDY 2 COMPARED

INDIVIDUALS GROUPED BY PROCESSING SPEED ADVANTAGE
FASTER IN LVF (LVF ADV) VERSUS FASTER IN RVF (RVF ADV)

ACCURACY IN LVF AND RVF ON FACE RECOGNITION
NUMBER OF FACES CORRECTLY RECOGNIZED

	<u>N</u>	<u>LVF</u> MEAN SD	<u>RVF</u> MEAN SD	<u>TOTAL</u> MEAN SD
STUDY 1				
LVF ADV	19	33.1 (9.0)	31.7 (8.7)	64.8 (16.6)
RVF ADV	6	38.3 (11.6)	44.0 (15.0)	82.3 (23.2)
STUDY 2				
LVF ADV	13	32.7 (8.1)	34.2 (6.6)	66.9 (13.7)
RVF ADV	12	33.3 (5.0)	31.5 (7.1)	64.8 (11.6)

SPEED IN LVF AND RVF ON FACE RECOGNITION
REACTION TIMES FOR CORRECT RESPONSES
(IN MSEC)

<u>STUDY</u>	<u>N</u>	<u>LVF</u> MEAN SD	<u>RVF</u> MEAN SD	<u>TOTAL</u> MEAN SD
STUDY 1				
LVF ADV	19	4129 (1182)	4731 (1399)	4430 (1224.8)
RVF ADV	6	4476 (1575)	4096 (1670)	4286 (1618.1)
STUDY 2				
LVF ADV	13	4589 (1338)	5243 (1997)	4915 (1608)
RVF ADV	12	4749 (1278)	4302 (1088)	4525 (1172)

HOW WELL DO PARTICIPANTS DO TWO THINGS AT ONCE?
STUDY 2 - FACE RECOGNITION AND RELATED SPEECH

AUDITORY RECOGNITION SESSION

INTRODUCTION

The purpose of the auditory recognition session was to determine whether there was any explicit delayed memory of the incidentally presented speech stimuli or, more simply, to assess whether subjects remembered the "unattended" stimuli. This is especially important in a situation where there is no performance difference between the face recognition without speech and the concurrent face and speech processing, as is the case between Study 1 and Study 2. In such a situation, one possible explanation for the lack of difference is that the speech was, in fact, not processed or that it was successfully ignored. Better than chance performance on the auditory session, however, would indicate that some resources had been allocated to processing the speech stimuli and thus rule out this possibility.

METHOD

AUDITORY STIMULI

The auditory recognition session included the 24 target word/voice combinations (old voice/old word) that were incidentally presented concurrently with the faces. It also included another 24 word/voice combinations as distractors. Rather than having distractors that were entirely new stimuli, the distractors were designed to help explore potential differences between the processing of word and voice. The distractors included 8 presentations from each of the following three categories:

1. target voices speaking new words (old voice/new word)
2. new voices speaking target words (new voice/old word)
3. new voices speaking new words (new voice/new word)

Four new male voices were used during the auditory recognition session. Each new male voice spoke four new words and two of the old words that had been used in the face recognition session. Each old voice spoke each of the six words it had originally spoken in the face recognition session, as well as two new words. A total of sixteen new words were chosen for the auditory session each of which was only presented one time. See Figure 7.

The same word list and imagery ratings used to select words for the face recognition session were also used to select the sixteen new distractor words for the auditory recognition session (Paivio, 1966). The mean duration of these sixteen words was 680 msec (SD = 120 msec). Voice segments for the auditory recognition session were recorded and brought into the computer exactly as they had been for the target words used in the face recognition session. Output decibel levels from the headphones were measured identically as for the targets. The mean for the 24 distractor words (No responses) was 60.5 dB S.P.L. (SD = 2.04 dB S.P.L.).

PROCEDURE

After the subjects completed the face recognition session, they were told that they were not yet finished. It was explained that they would now be hearing voices saying a single word. The subjects were instructed to identify as YES any combination of a voice speaking a particular word that they had heard during the face session. They were told to answer yes by pressing the left facing arrow key. They were instructed to identify as NO any other combination of voice and word. They were told to answer no by pressing the right facing arrow key. YES and NO were affixed above these

keys to remove any ambiguity. These directions were also given to them in writing (See Appendix B.) Since there were 24 targets and 24 distractors, the YES/NO response ratio during the auditory recognition session was one to one allowing a 50% correctness rate to be achieved by chance alone.

To begin the auditory recognition session the subjects pressed the enter key. The visual fixation circle used during the face recognition session was used as the warning signal for the auditory target. It was immediately followed by a blank screen while either a target or distractor voice/word file was played. Pressing the yes or no key served to trigger the presentation of the next warning signal followed by the next voice/word combination. The presentation of voice/word files was completely randomized for each subject.

STUDY 2
FIGURE 7

DISTRACTOR WORDS USED IN DELAYED AUDITORY RECOGNITION
SESSION

OLD VOICE #1

corn
tool

OLD VOICE #2

comedy
violation

OLD VOICE #3

table
toy

OLD VOICE #4

gaiety
malady

NEW VOICE #1

bullet
stone
(trumpet)
(insect)

NEW VOICE #2

strength
emotion
(whale)
(vehicle)

NEW VOICE #3

butterfly
plant
(grief)
(sensation)

NEW VOICE #4

death
knowledge
(robbery)
(mood)

NOTE: The words in parenthesis are the old words assigned
to those new voices

STUDY 2
RESULTS
ACCURACY AND SPEED ON DELAYED SPEECH RECOGNITION

Both percentage of words correctly recognized and reaction time results are reported in Table 4. Subjects correctly recognized 82.2% of the speech stimuli. This is substantially better than the 50% correctness level that would have been expected by chance. The number correct for each word type, i.e. old voice/new word, old voice/old word, new voice/new word and new voice/old word was expressed as a percentage due to the fact that there were differing numbers of stimuli in each category. An arcsine transformation was applied to each percentage, as is recommended for proportional data prior to using it in an analysis of variance. An ANOVA with repeated measures on the four categories of speech stimuli was carried out. A main effect for word type was found ($F(3,72)=16.91$, $p<.005$). A similar analysis of the reaction time data also revealed a main effect of word type ($F(3,72)=3.90$, $p<.02$).

Additionally, assessment of difficulty of identifying categories of word types is relatively consistent based both upon reaction time and percent correct. Not surprisingly, new voice/new word is easiest to correctly identify according to both measures. An old voice with a new word is the next easiest. Based upon percent correct, the most

difficult category is old voice old word; however, based upon reaction time the most difficult is an old word/new voice. Since subjects were told to identify as yes only those combinations of word and voice they were sure they heard while processing the faces, there might well have been a small response bias toward saying no; therefore, where reaction time and percent correct do not correspond, the reaction time data most probably reflects actual difficulty since it is free of any potential response bias. Thus it seems likely that old word/new voice was the most difficult category.

It seems clear from these results that despite the greater repetition of voice compared to word (36 times versus 6 times respectively), word was the most salient determinant of which categories of speech were easiest. Both of the two easiest categories, i.e. new voice/new word and old voice/new word could be correctly excluded from identification simply based upon perceiving the new word alone. However, having a new voice does not have the same effect since the category of new voice/old word produces the worst performance (based upon reaction time).

A further suggestion of the saliency of word is provided in the pattern of correlations between percent correct performance on the different word types. Correlations between the categories of old voice/new word

and new voice/new word ($r(25)=.44$, $p<.04$) and the categories of old voice/old word and new voice/old word ($r(25)=-.42$, $p<.05$) are in the opposite direction. Responses based solely upon recognition of word could explain these observations. If the response to old voice/new word and new voice/new word were made based upon recognition of new word as being new and thus answering "no", in both cases the answer would be correct and one would expect a positive correlation such as the one observed. On the other hand, if for old voice/old word and new voice/old word the response was based upon recognizing the familiarity of the old word and answering "yes", it would be correct in one instance and incorrect in the other which would produce a negative correlation between performance in the two categories, just as was observed.

It also should be noted, parenthetically, that had a more typical paradigm for speech recognition been used, i.e. simply old versus new, the overall correctness rates on the speech recognition session would have been similar to those for the category of new voice/new word, viz. 96.5%.

As described previously, the concurrently presented speech was incidental so that no explicit memorizing of the speech was likely. Additionally, the delayed speech recognition session was intended as a surprise. In order to assess whether the surprise aspect of the testing was

carried off, it would have been good to have included a question on the post session questionnaire asking subjects if they were actually surprised at being tested on the speech stimuli. Unfortunately, such a question was not included. However, many, if not most, subjects did not seem to expect any further testing. The face recognition session lasted approximately 30 to 45 minutes. After that length of time, most subjects began to get ready to leave and had to be told that they were not yet finished.

(It should be noted that the timer for auditory reaction times began simultaneously with the presentation of the word and thus the reported reaction times include the word length. However, since the mean length of reaction time per category of word type is virtually identical, there should be no confounding effect of this programming approach.)

TABLE 4
STUDY 2

PERFORMANCE ON DELAYED SPEECH RECOGNITION

PERCENT CORRECT BY WORD TYPE ON DELAYED SPEECH RECOGNITION

<u>N</u>	<u>OLD VOICE</u> <u>NEW WORD</u>	<u>OLD VOICE</u> <u>OLD WORD</u>	<u>NEW VOICE</u> <u>NEW WORD</u>	<u>NEW VOICE</u> <u>OLD WORD</u>	<u>** TOTAL</u> <u>%CORRECT</u>
	MEAN (SD)	MEAN (SD)	MEAN (SD)	MEAN (SD)	MEAN (SD)
25	90.5 (12.1)	74.2 (12.0)	96.5 (10.5)	84.0 (20.6)	82.2 (7.0)

CORRECT REACTION TIME BY WORD TYPE ON DELAYED SPEECH
RECOGNITION
(IN MSEC)

<u>N</u>	<u>OLD VOICE</u> <u>NEW WORD</u>	<u>OLD VOICE</u> <u>OLD WORD</u>	<u>NEW VOICE</u> <u>NEW WORD</u>	<u>NEW VOICE</u> <u>OLD WORD</u>	<u>TOTAL</u>
	MEAN (SD)	MEAN (SD)	MEAN (SD)	MEAN (SD)	MEAN (SD)
25	3065 (1134)	3322 (998)	3024 (919)	4022 (2613)	3358 (1210)

** The category of OLD VOICE OLD WORD had 24 target; whereas the other categories each had only 8 targets. Thus the total % correct is not the mean of each of the category percentages

STUDY 2
RESULTS
RELATIONSHIP BETWEEN FACE RECOGNITION AND DELAYED SPEECH
RECOGNITION

Once it was clear that the incidental speech had been processed, based upon better than chance performance during the auditory session, analyses were performed to examine the relationship between subjects' face recognition accuracy and their delayed speech recognition performance. If good performance on face recognition were to predict good performance on speech recognition, a facilitative process would be suggested. On the other hand, if face and speech recognition performance were negatively correlated, a trade-off in resources would seem more likely. Furthermore, any differences in terms of the relationship of the LVF and RVF to speech recognition might be clues to differences in the underlying processes in the right and left hemispheres.

Correlations between total auditory performance and total face recognition accuracy, as well as for face recognition accuracy in each visual field with total auditory performance and accuracy in the category of old voice/old word, were calculated and are reported in Table 5. In general, good performance on the face recognition task was related to good performance on the delayed speech recognition. This was true for both visual fields. For

instance, the correlation for LVF performance and the category of old voice/old word was as follows: $r(25)=.44$, $p<.03$ and for RVF performance: $r(25)=.55$; $p<.01$.

The relationship between face recognition and speech performance was also looked at across time. There is already clear evidence that subjects improve their face recognition performance over the course of the experiment, but there is no way to directly assess whether subjects are becoming better at associating speech and faces over time. Since it would take time for an association to form between the related speech and face, face performance in the latter blocks would be most likely to manifest such a connection. A difference in the degree of relatedness between face and speech performance in these latter blocks could be meaningful. It might suggest that the association is being learned and that making the connection between faces and speech is providing some of the basis for the general observation that good performance on the face recognition task predicts good performance on speech recognition. Such evidence could pose an alternative explanation for the correspondence of face and speech recognition performance to one that simply posits the superior processing capabilities, in multiple realms, of some individuals as compared to others.

Correlations were calculated for the number correct in the left and right visual fields in each block with the total number correct in the auditory session and also with the number correct in the category of old voice old/word. As can be seen in Table 5, significant positive correlations between the face recognition performance and the auditory performance begin to emerge in Block 3 and appear for either total auditory performance or the category of old voice/ old word for each subsequent block. Thus, there is at least the suggestion that the association between speech and face is being learned over time and that making the connection might be related to the correspondence between performance on face and on speech recognition.

Although, general analysis of male female difference was not done in these studies due to the sensitivity of ANOVAs to uneven cell size, a male female difference was observed in detecting the relationship between face and speech. Significantly fewer males detected the relationship between face and voice and thus answered yes to the following post session question: "Do you think that there was any connection between a face and a voice?" Fifteen of 19 females correctly answered yes to this question, but only 1 of 6 males did. This difference was significant based upon Fisher's Exact test ($p < .006$).

Dividing subjects into LVF ADV and RVF ADV processing speed groups was useful in considering the relationship between speed, accuracy and hemispheric lateralization on face recognition performance and in examining individual differences. It is of interest to see whether these groups go on to perform the same or differently on the speech recognition task. Their performance on the speech recognition session is summarized in Table 6. A group by word type 2 by 4 repeated measures ANOVA was performed. The main effect of group was significant ($F(1,23)=6.45$, $p<.02$). The group that was relatively faster in the RVF while processing the faces, identified more of the speech stimuli correctly. There was no evidence of a difference in response speed between these groups ($F(1,23)=1.94$, $p=.18$).

Although there was not a significant group by word type interaction ($F(3,69)=1.24$, $p=.34$) for the percent correct, in an exploratory study such as the current one, it was felt that an unorthodox analysis might be tolerated for the purposes of suggesting speculations and formulating questions. Therefore, separate analyses were done for each word type in an attempt to discern whether there was even a suggestion of one category of word contributing more to the overall difference in performance than another. Performance on old voice/ new word was significantly better for the RVF ADV group ($F(1,23)=8.10$, $p<.02$) and performance on new voice

/new word approached being significantly better ($F(1,23)=3.94, p<.06$). There was no evidence for a difference between the RVF and LVF ADV groups on the categories of old voice/old word or new voice/old word. Thus, there is a small possibility that the overall performance difference observed might have been unequally contributed to by superior performance in these two categories by the RVF ADV group (or inferior performance in these two categories by the LVF ADV group). It should be noted, for future discussion, that correct responses and thus high performance in both of these categories can be achieved on the basis of correctly recognizing a new word alone.

TABLE 5
STUDY 2

PEARSON CORRELATIONS BETWEEN FACE AND SPEECH RECOGNITION
ACCURACY

		<u>SPEECH PERFORMANCE</u>	
		TOTAL AUDITORY	OLD VOICE OLD WORD
<u>OVERALL</u>			
	LVF	$r(25) = .36!$	$r(25) = .44^*$
	RVF	$r(25) = .45^*$	$r(25) = .55^{**}$
	TOTAL CORRECT	$r(25) = .44^*$	$r(25) = .54^{**}$
<u>BLOCK BY BLOCK</u>			
<u>BLOCK 1</u>			
	LVF	$r(25) = -.02$	$r(25) = .12$
	RVF	$r(25) = .10$	$r(25) = .12$
<u>BLOCK 2</u>			
	LVF	$r(25) = .30$	$r(25) = .21$
	RVF	$r(25) = .21$	$r(25) = .32$
<u>BLOCK 3</u>			
	LVF	$r(25) = .14$	$r(25) = .31$
	RVF	$r(25) = .42^*$	$r(25) = .30$
<u>BLOCK 4</u>			
	LVF	$r(25) = .13$	$r(25) = .27$
	RVF	$r(25) = .22$	$r(25) = .46^*$
<u>BLOCK 5</u>			
	LVF	$r(25) = .40^*$	$r(25) = .30$
	RVF	$r(25) = .41^*$	$r(25) = .38!$
<u>BLOCK 6</u>			
	LVF	$r(25) = .33$	$r(25) = .35!$
	RVF	$r(25) = .27$	$r(25) = .41^*$
!	p<.10		
*	p<.05		
**	p<.01		

TABLE 6
STUDY 2

INDIVIDUALS GROUPED BY PROCESSING SPEED ADVANTAGE
FASTER IN LVF (LVF ADV) VERSUS FASTER IN RVF (RVF ADV)
PERCENT CORRECT BY WORD TYPE ON DELAYED SPEECH
RECOGNITION
(IN MSEC)

<u>STUDY</u>	<u>N</u>	<u>OLD VOICE</u> <u>NEW WORD</u> MEAN (SD)	<u>OLD VOICE</u> <u>OLD WORD</u> MEAN (SD)	<u>NEW VOICE</u> <u>NEW WORD</u> MEAN (SD)	<u>NEW VOICE</u> <u>OLD WORD</u> MEAN (SD)	<u>TOTAL*</u> MEAN (SD)
LVF ADV	13	84.6 (13.6)	74.4 (10.9)	93.3 (14.1)	79.8 (23.7)	80.1 (6.8)
RVF ADV	12	96.9 (5.7)	74.0 (13.7)	100.0 (000)	82.0 (16.4)	84.5 (6.6)

* The category of OLD VOICE OLD WORD had 24 target; whereas the other categories each had only 8 targets. Thus the total % correct is not the mean of each of the category percentages

STUDY 2 SUMMARY OF OBSERVATIONS

FACE PROCESSING

- * No longer evidence for RH being faster than LH. RH ADV not in evidence in the presence of speech (but no significant study by visual field interaction).
- * Performance is maintained. No evidence of slowing down or of decrease in accuracy in the presence of speech.
- * Most subjects no longer faster in RH than in LH - equal breakdown of subjects with LH ADV and RH ADV. Difference between distributions in Studies 1 & 2 is not, however, significant ($df=1$, $X^2=3.13$, $p<.08$).
- * LH ADV group no longer more accurate overall. Comparing LH ADV groups in Studies 1 & 2, there is greater loss of accuracy in LH than in RH ($F(1,46)=6.50$, $p<.01$).
- * Speed and accuracy no longer coincide within the LH, but are crossed between the LH and RH. Speed in the LH predicts accuracy in the RH ($r(25)=-.41$, $p<.04$) and this is significantly different from the relationship between speed in the RH and accuracy in the LH ($r(25)=-.12$, $p<.56$) ($t=2.07$, $p<.05$).

And in general, most subjects show reversed hemispheric advantage based upon speed and accuracy, but in Study 1 most subjects show a consistent advantage. Distribution of reversed and non-reversed advantage is different between the studies ($df=1$, $X^2=5.30$, $p<.03$).

STUDY 2

SUMMARY OF OBSERVATIONS

SPEECH PROCESSING

- * Even though the speech was incidental, subjects seem to be able to do two things at once. With no decline in face processing, auditory processing is well above chance (82.2%) with correctness level for new voice/new word at 96.5%.

- * Subjects who were faster responding correctly to faces in the LH, correctly recognized a higher percent of the speech stimuli ($F(1,23)=6.45$, $p<.02$).

- * Significant main effect for word type based upon percent correct and reaction time, with new voice/new word the easiest and new voice/old word probably the most difficult.
 (percent correct: $F(3,72)=16.91$, $p<.005$)
 (reaction time: $F(3,72)=3.90$, $p<.02$)

- * Despite a design with greater repetition of voice (36 repetitions of a particular voice and only 6 repetitions of a particular word), performance on categories of word type point toward word being more salient than voice.

- * Face recognition performance in both the RH and LH is positively correlated with speech recognition performance. This relationship only emerges in Block 3 and later.
 (total:RH: $r(25)=.36$, $p<.10$; LH: $r(25)=.45$, $p<.05$)
 (OVOW: RH: $r(25)=.44$, $p<.05$; LH: $r(25)=.55$, $p<.01$)

- * Females are more likely than males to correctly report a connection between a face and a voice.
 (Fisher's Exact Test: $p<.006$)

STUDY 2
STUDY 2
FACE RECOGNITION WITH RELATED SPEECH
DISCUSSION

There was no significant decline in either speed or accuracy for face recognition with related speech in Study 2. Thus, faces can be said to have been processed equally well with and without speech. Furthermore, there is evidence of high levels of delayed memory for speech despite the fact that it was presented incidentally. Subjects were clearly able to do two things at once without detriment to the primary, and rather difficult, face recognition task.

This is not the most typical finding. In the context of divided attention, it is often not the case that two forms of processing proceed so well simultaneously. This less common situation, one where two things can be done at once without loss of performance to either, is considered to be most interesting (Pashler, 1990). Of course, while it is known that face processing performance did not decline, speech recognition was not tested by itself; so that, it can not definitively be said that there would not have been a decline in speech recognition performance. However, accuracy in the word type category of new voice/new word was 96.5% correct. In a simple, more typical, yes/no identification paradigm for testing speech recognition, one

not complicated by attempting to discern differences between the saliency of voice and word, this category would be equivalent to "no" and would be indicative of the overall level of performance. Thus, it is clear that speech recognition performance was at a very high level.

Important to considering the performance results atypical is the fact that the speech presented in this study was presented incidentally. Questions concerning explicit memory for "unattended" information have generated a literature of their own. The difficulty that is generally associated with explicit remembrance of stimuli presented incidentally is illustrated in a study done by Kellogg and Dare (1989). Their study involved incidental presentation of visual words concurrently with the performance of arithmetic. The experimental design was similar to the current work in that it included a surprise post session recognition test of the incidentally presented words. Direct comparisons of the level of explicit memory are not possible since their results were reported in terms of Signal Detection Theory; however, the fact that great difficulty was associated with the recognition session is expressed in the following: "Pilot testing indicated that it was critical that subjects be encouraged to search their memory carefully and perform as well as possible on the recognition test. Otherwise, they quickly became frustrated

and gave up trying to remember" (Kellogg & Dare, 1989, p.410). This contrasts with the actual performance results observed from the current study and also with the anecdotally reported ease with which subjects "whizzed" through the auditory recognition session. Thus the results from Study 2 are not typical from the viewpoint of explicit memory of incidentally presented information, as well as of divided attention.

It seems that the ecological importance of the particular form of information processing involved in the current study - simultaneous face and speech processing - ought to be pertinent to the good performance. Indeed, it would be advantageous to have an enhanced ability to process faces and speech concurrently. The relatedness of the face and speech should also not be forgotten in viewing this unexpectedly good performance. Redundancy was potentially provided at the encoding stage of processing. If an association between a face and its related speech were made, this could have facilitated face recognition. Such multimodal facilitation might have offset some of the detrimental effects of the increased processing load. Simply examining total performance might not be indicative of this possibility.

One source of evidence for this having occurred might be provided by looking at performance across time. Better

performance in the latter blocks, as compared to the earlier blocks, might suggest that such facilitation had occurred. Since it would take some time for an association to form between the related speech and face, these latter blocks would be most likely to manifest the benefits of such a connection. In fact, however, a cursory look at performance across time indicates that the overall number of faces recognized correctly in the latter blocks of Study 2 as compared to Study 1 is lower. Thus, face performance, per se offers no evidence for any facilitating effect of the relatedness between face and speech on face recognition. (formal statistical analysis was not done since the differences were so slight.)

The performance between Studies 1 and 2 does not change significantly - does not get better and does not get worse. Thus, the current series of studies do not fit neatly into either the category of divided attention or of multimodal facilitation. Against this absence of dramatic changes in performance for face recognition, however, alterations in the patterns of hemispheric laterality emerged. Although the overall performance was found to be the same, there is evidence that the processes underlying that performance have changed. Without having done these studies in the context of exploring hemispheric lateralization, these changes would have remained hidden.

For face recognition in the absence of speech, the stimuli presented to the RH were processed significantly faster than those presented to the left and significantly more individuals were relatively faster for correct responses to faces in the RH than in the LH; whereas, with related speech present, this scenario changes. There is no longer evidence for RH responses being faster than LH ones. There is also no longer a larger group of individuals who are faster in their RH responses compared to their LH ones. The distribution of individuals into these two types was approximately equal and the difference in the distribution of individuals between the two studies approaches significance. Basically, then, any evidence for a RH ADV for faces disappears with the concomitant processing of speech.

This is parallel to the findings in two studies mentioned earlier. Klein, et al. (1978) found that when written words and faces were presented concurrently and attention was directed first to faces then to words, or alternately, first to words then to faces, a RH ADV exhibited when faces were attended to first disappeared when words were attended to first. But a LH ADV for words persisted in both attentional sequences. In a 1985 study, Umiltà et al. observed that a RH ADV for face discrimination disappeared between a single task and divided attention

situation; whereas, a LH ADV for words persisted in both cases. Similarly, in the current studies, although not being compared to the strength of a LH ADV for words, the RH ADV for faces proves fragile in the presence of additional processing and potentially divided attention.

In Study 1, in addition to there being a RH ADV in terms of response time, there is also evidence for a specialized form of LH superiority. This is indicated by the overall, and particularly LH, superior performance on face recognition of a handful of individuals who were faster in responses to faces in their LH relative to their RH. In Study 2, a similar group of high performing subjects with a LH ADV does not exist. When comparing the LH ADV group in Study 1 and the corresponding LH ADV group in Study 2, a notable observation is the decline in the number of faces correctly recognized, especially in the LH.

It seems that concurrent processing of speech with faces might simultaneously interfere with the emergence of an overall RH ADV, in terms of speed of response to faces, and also of a highly superior LH processing style, one that might, as discussed previously, be more reliant on featural processing. Thus, speech processing may upset lateralized face processing, and in paradoxical ways, possibly playing a role in the non-emergence of an overall RH ADV as well as a specialized LH ADV exhibited by a subset of individuals.

Possible explanations for the dynamics of how this occurs are based upon the supposition that speech engages the LH more than the RH; however, it should be kept in mind that this assumption was not directly tested in relation to the speech presented in the current studies, but is based upon other research. Since one theme of the current dissertation is that hemispheric lateralization is dynamic, it is recognized that even this well preceded assumption should not be accepted as an absolute fact, thus adding to the tentative nature of any potential explanations offered.

At the same time, however, there is evidence from the current study that word was more salient than voice. Despite a design involving greater repetition of voice, with 36 repetitions of a particular voice and only 6 repetitions of a particular word, the word type categories with best performance, viz. new voice/new word and old voice/new word, could both be distinguished based upon recognition of a new word alone. But the category that contains novelty in relation to voice, new voice/old word, produced the worst performance based upon reaction times. As mentioned in the Introduction, the processing of words in particular is strongly associated with the LH, much more so than the processing of voice or of emotional intonation. The observed saliency of word over voice coupled with this fact does provide some more direct basis for the supposition of

greater LH involvement of the processing of speech in this experiment.

The disappearance of the RH ADV in terms of response time to faces in the concurrent face and speech condition might be considered in terms of Kinsbourne's idea of priming (Kinsbourne & Byrd, 1985). It could be suggested that the presence of speech processing in the LH leads to increased activation which speeds up other LH responses, including responses to faces. Although, the speech and faces are presented simultaneously, the speech does precede the actual response to the face and thus could be in a position to prime that response. Or formulated in a somewhat different way, also based upon Kinsbourne, the processing of speech in the LH could result in the directing of attention to the contralateral visual field - the RVF. Thus when faces are presented to the RVF, since attention is more directed there, the responses to those faces are faster than when they are presented to the LVF. Unfortunately for these interpretations, the RVF (LH) responses to faces do not speed up between the silent face (Study 1) and the faces with speech studies (Study 2); so that, the support for this model is not as strong as it might be. What is observed, however, is a non-significant trend for the RVF (LH) responses to faces to slow down less than those in the LVF (RH). LVF (RH) responses slow down by 453 msec between

Studies 1 and 2 and RVF (LH) responses slow down by 212 msec. Support for the priming explanation increases when the (approaching significant) alteration in the distribution of subjects with a LH and RH response time ADV is taken into account. When speech is present, the typical pattern in terms of response speed is no longer that most subjects exhibit faster responses in the RH relative to the LH. Subjects are equally divided. Perhaps the effects of priming, brought about by concurrent processing of speech, lead to enough of an increase in the speed of LH responses to faces to result in the alteration of the typical pattern. While the evidence for a priming or attentional effect is not overwhelming, the observed patterns in relation to response time to faces are certainly consistent with such an explanation.

What about the question of the non-emergence of a highly efficient LH processing style in the presence of speech? Since speech processing is more strongly associated with the LH than the right, this observation might be understood in terms of interference or competition for resources. The larger decline in the number of faces recognized in the LH (RVF) compared to the RH (LVF) bolsters this interpretation. It may simply not be possible to maintain a specialized LH form of face processing, one that might, as discussed, be based upon featural analysis, in the

context of utilizing LH resources for speech processing. However, there is a glitch in this interpretation. This occurs in the fact that there is not an overall decline in LH performance on face processing. The interference effect, if occurring at all, is circumscribed, limited to obstructing the emergence of a group of individuals exhibiting a highly efficient LH processing style. Is it conceivable, then, that even within the LH faces can be processed in multiple ways, some of which are more in conflict with, or require more closely the same resources as, speech processing than others? If the interference explanation just described is correct, then this must be the case.

If the potential explanations for observed alterations in hemispheric advantage, just described, sound like double talk, it is not surprising. How can the concurrent processing of speech with faces both interfere with and prime face processing at the same time? If the specifics of the observed advantages are looked at, it may be possible to reconcile these seemingly contradictory ideas. First, the RH ADV described for face processing by itself (Study 1) is an advantage in terms of speed, or possibly efficiency, but not of accuracy. Priming, conceived as either a spillover of activation or as heightened attention, could be considered to lead to faster response times for any

processes involving that resource pool. In this case, we can equate the resource pool, as Polson and Friedman might, with the left hemisphere. Thus, processing speech in the LH could tend to speed up LH responses including those to faces. This speeding up of response times could counteract, only for the LH, any slowing down of responses due to additional processing load, between face processing alone and face processing with speech, and to tend to make more individuals respond to faces relatively faster in the LH than in the RH. On the other hand, the LH ADV processing style in Study 1 was associated with being faster in the LH than in the RH, but more importantly, with being significantly more accurate overall. Perhaps the actual use of the same or closely related resources (having a close functional cerebral distance, according to Kinsbourne) is simultaneously subject to an interference effect. On the one hand, an advantage of speed is being described, and on the other, actual proficiency or accuracy. These are not one and the same. Crucial to the acceptance of this reconciliation between an interference and a priming effect is the idea, mentioned above, that there may be more than one way to process a face even within the LH and that the type of face processing which seemed to favor the LH in Study 1 was somehow different processing from the face processing performed in the LH in Study 2. The Study 1

process would have to have been more closely tied to the same resources involved in speech processing and thus more subject to disruption by it. Perhaps speech activates some highly feature oriented visual process involved in seeing speech, particularly focused on the mouth (even when the face is not moving) which conflicts with the use of features for recognition purposes.

Moving away from this highly speculative discussion, further elucidation of the meaning of the LH ADV in Study 2 is provided by the observations concerning the relationship between performance on face recognition and performance on delayed speech recognition. These observations are among the most interesting in this entire series of studies. Those individuals who have a LH ADV in processing faces, who are relatively faster in the LH than in the right, subsequently go on to perform significantly better on the delayed speech recognition test. One interpretation of this observation is consistent with the idea of some form of priming occurring in the LH. It is also consistent with and lends support to the assumption that speech processing for these individuals engaged the LH more than the RH. According to this interpretation, for certain individuals, activity occurring during the encoding stage of one process - speech processing - is being indirectly reflected in the output stage of an entirely different process, a process

that is occurring in a separate modality, viz. face processing. And, this effect is lateralized. The question is why are relatively faster responses on the faces in the LH, for these individuals, related to better performance on the speech processing. Are faster responses indicative of more or better encoding of the speech or greater attention being directed to the speech stimuli which then results in better memory for them? Or is there some hidden trade-off in processing taking place between faces and speech?

An additional source of information in trying to understand this observation can quite speculatively be provided by the unorthodox separate analyses by category of word type of the processing speed advantage groups in Study 2. This analysis tentatively suggests that the LH ADV group in study 2 compared to the RH ADV group tended to perform better only in the categories of new voice/new word and old voice/new word. (Or, from a different viewpoint, the RH ADV group performed worse in these two categories.) The correct response on the speech recognition test for both of these categories of speech can be achieved by recognition of a new word. Thus, detection of new word may have been performed more poorly by the RH ADV group and may have been performed in a superior manner by the LH ADV group. These speculative observations, in relation to high performance by the LH ADV group on word judgements, are consistent with the

interpretation presented above of the faster responses to faces among the LH ADV group in Study 2 being related to, or perhaps primed by, the speech processing, possibly the processing of words in particular. And this processing is most probably simultaneously engaging the resources of the LH. This interpretation could be tested by altering the speech signal so that the saliency of word is further removed and the signal is predominately distinguishable based upon voice alone. In this case, one would have to predict that the observed relationship between relatively faster LH responses and superior speech recognition performance should be altered.

Related to the discussion of processing speed advantage is the observation that faster response times on faces in the LH (RVF) are not positively correlated with greater accuracy within the LH, as was the case in the processing of faces alone, but with greater accuracy in the right. Perhaps there is some most efficient complementary form of processing between the hemispheres which involves fast response in left - good face performance in right and overall good delayed speech performance. The LH ADV groups may be displaying some maximally efficient form of processing in the concurrent situation. It does not manifest itself in superior face performance, but in superior speech recognition performance while maintaining

equal face performance. If the faster LH response to faces is being driven by the processing of speech, then this may be indicative of a division of labor between the hemispheres, or some degree of specialization in the dual processing situation, faster in the left, indicative of more speech processing and better in the RH on face processing. This type of view would be consistent with the developmental scenario raised in the Introduction. This interpretation posited the development of face recognition specialization in the right hemisphere due to an already established specialty for speech in the right. Related to this, a question of interest would be whether there is any connection, within an individual, of the observed, maximally effective, processing styles. That is, would there be a group of high performing individuals who when performing face recognition in the absence of speech, as in Study 1, would manifest the faster in LH (RVF) and overall more accurate approach. When performing face recognition with related speech they would manifest the faster in LH, predicting more accurate in RH and overall better at speech recognition. This could be tested by exposing the same individuals to both the face alone and the concurrent face and speech processing situations.

One last observation worth considering is the positive correspondence between face recognition performance in both

visual fields and delayed speech recognition performance. Not only is there evidence that subjects were able to do two things at once, but these positive correlations provide evidence that a particular individual who did well on face recognition also did well on speech recognition. This result is consistent with the continued good performance in the concurrent processing situation. If there had been a negative correlation between face recognition and speech recognition, i.e. those who performed better on faces did worse on speech, the results would be more consistent with the idea that attention had been divided between faces and speech, but there is no such sign of a trade off of attention. One might be tempted to argue that this is an uninteresting finding that is simply a manifestation of the fact that certain individuals have superior cognitive processing and attentional abilities and would simply do well on any of a number of tasks. The correspondence in performance between these tasks is simply a reflection of their general information processing or attention directing prowess. Even if this argument were correct, however, unless one accepts some notion of individuals whose performance is superior in every single sphere, it is still of interest that performance in these particular processing realms is connected and that attention can be "directed" to both of these types of stimuli simultaneously. Furthermore,

it is noteworthy that when viewed across time, there is some indication that the positive relationship between face and speech performance is only evident after familiarization with the stimuli has been possible. These positive correlations only emerge when face recognition performance after Block 3 is considered. While quite tentative, this may suggest that multimodal facilitation may be taking place. It may be manifesting itself, if not in overall better performance on face recognition, in this late emerging positive correspondence between face and speech performance. Thus, those individuals who are attending more to the speech and who are better at forming the association between the faces and the speech, might be able to do well on both faces and speech partly due to the use of this redundancy. Processing resources directed toward the speech do not result in an overall detriment in performance because the association and redundancy results in face recognition occurring in a somewhat different way.

CHAPTER 4
DOES CONCURRENT PROCESSING OF UNRELATED FACES AND SPEECH
RESULT IN DIFFERENT EFFECTS FROM THOSE PRODUCED BY
PROCESSING RELATED SPEECH?

STUDY 3 - FACE RECOGNITION WITH UNRELATED SPEECH

INTRODUCTION

Real life recognition of individuals can be accomplished based upon redundant multimodal information. For modern humans, this includes mainly visual information in the form of the face and auditory information contained in an individual's speech. The study of face recognition with related speech (Study 2) attempted to approximate this ecologically valid situation by providing both a face and a related voice at the stage of facial encoding.

As mentioned in the Introduction, evidence exists indicating that having both a face (non-lateralized) and a voice aids in recognition of individuals; although in that case multimodal information was provided at the point of recognition (Melara, et al., 1989). One question that guided the current study was whether having redundant multimodal information at the face encoding stage affected the observed patterns of hemispheric lateralization and the proficiency of face and speech recognition in Study 2. This question is particularly interesting considering the

positive correlation between face and speech recognition performance that was observed in that Study. Those who did better on processing the faces also did better on delayed speech recognition. Another important observation in Study 2 was the lack of a significant decline in face recognition in the presence of speech. Thus, a further issue of interest is whether the redundancy of face and speech "took the edge off" the face recognition performance decrement that might have been expected due to increased processing load.

The purpose of Study 3 was to look more closely at these questions. The simplest way to do this was to present the same lateralized face recognition task used in Study 2, but with concurrent unrelated speech. In this way, there would be concurrent multimodal stimuli for processing, but the speech would not potentially provide redundant information related to face recognition. The design would no longer even approximate the ecologically valid situation of bimodally recognizing an individual through face and speech.

METHOD

SUBJECTS

The subjects were recruited and screened exactly as they were for Studies 1 and 2. They were 25 right handed males and females (6 males and 19 females) with self reported normal hearing and with a mean age of 22.8 (SD=5.8) years. The data from 5 additional subjects were dropped. Reasons for this included the following: anticipatory keying responses - 2; misunderstood directions - 1; improper seating - 1; chance performance - 1.

PROCEDURE

The procedure for this study was identical to that for face recognition with related speech (Study 2) with one major difference. In this study the same auditory stimuli were used as were used in Study 2. However, a particular voice and subset of 6 words was not presented in association with a particular face. The set of 24 auditory stimuli was presented in a totally randomized fashion for each block of 24 faces. Randomization order was unique for each subject.

STUDY 3
FACE RECOGNITION RESULTS
ACCURACY AND REACTION TIMES IN LVF AND RVF ON FACE
RECOGNITION

ACCURACY

The mean number correct for the faces was 64.0 (SD=14). This is an overall correctness level of 44.4% which is above the 25% chance level. This was 5 fewer faces correct than in the processing of silent faces, but the difference was not significant based upon an ANOVA with one between group factor on study and one within group factor on visual field ($F(1,48)=.26$, $p=.62$). Subjects got a mean of 32.6 (SD=8.4) faces correct in the LVF and 31.4 (SD=7.8) faces correct in the RVF, but there was no difference in the accuracy between the visual fields ($F(1,24)=.63$, $p=.44$) as determined by a repeated measures ANOVA.

The effect of block was also examined and a significant block effect ($F(5,120)=12.85$, $p<.001$) and a significant linear trend ($t=5.35$, $p<.001$) were found. The percentage of faces correctly recognized increased from 34.6% in Block 1 to 55.0% in Block 6. Thus, as in the processing of silent faces and face recognition with related speech, the number of faces correctly recognized increased across time. Once again, there was no difference in the performance between the visual fields over time as indicated by the lack of a

visual field by block interaction ($F(5,120)=1.05$, $p=.40$).

(Block data are in Appendix A, Table A8.)

REACTION TIME/SPEED

As in Study 1 and Study 2, a reciprocal square root transformation was applied to the mean total correct reaction time data to correct for lack of homogeneity of the variances. (Analysis based upon non-transformed measures is in Appendix A, Table A1.) Transformed data were used for inferential statistics, but raw data are presented in Table 7.

The total mean correct reaction time was 4366 msec ($SD=1067$). The mean correct reaction time in the LVF was 4357 msec ($SD=913$) and in the RVF was 4375 msec ($SD=1329$). This 18 msec difference was not significant based upon a repeated measures ANOVA ($F(1,24)=.38$, $p=.54$). Thus, just as in Study 2 and contrary to Study 1, there is no evidence of a difference in speed between the visual fields. There was also no evidence of a difference in the reaction times between the visual fields for the incorrect responses which were 5142 msec ($SD=1500$) in the LVF and 5336 msec ($SD=1715$) in the RVF ($F(1,24)=1.18$, $p=.29$). The mean correct

responses were significantly faster than the incorrect ones ($F(1,24)=27.7$, $P<.001$).

The mean correct reaction time in the study of face recognition with random speech (Study 3) was 363 msec faster than in the study of face recognition with related speech (Study 2) and 30 msec faster than in Study 1, as can be seen in Table 7. Data from Study 2 and Study 3 were analyzed together using an ANOVA with one between group factor on study and one within group factor on visual field. The difference in response speed was not significant as indicated by the lack of a main effect of study ($F(1,48)=.69$, $p=.42$).

A two by six repeated measure ANOVA was used to examine the decrease in reaction times across blocks. It was found that this decrease was significant ($F(5,120)=4.82$, $p<.001$) and there was a significant linear trend ($t=-2.86$, $p<.01$). Once again, subjects became both more accurate and faster with practice. However, there was no block by visual field interaction ($F(5,120)=.93$, $p=.47$) indicating that there was no evidence of a visual field difference in this process. (Block data are in Appendix A, Table A9 and incorrect reaction times are in Table A10.)

TABLE 7
STUDY 1 - STUDY 3 COMPARED
FACE RECOGNITION REACTION TIME IN LVF AND RVF
REACTION TIMES FOR CORRECT RESPONSES
(IN MSEC)

<u>STUDY</u>	<u>N</u>	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
STUDY 1	25	4213	(1260)	4579	(1458)	4396	(1294)
STUDY 2	25	4666	(1285)	4791	(1663)	4729	(1401)
STUDY 3	25	4357	(913)	4375	(1329)	4366	(1067)

STUDY 3
RESULTS
RELATIONSHIP BETWEEN SPEED AND ACCURACY

There is no evidence of a relationship between speed and accuracy. This is indicated by the lack of correlation between the mean correct reaction time and the total faces correct ($r(25) = -.03$; $p = .89$). This differs markedly from both Study 1 and Study 2 where there was, to varying degrees, a positive correlation between speed and accuracy with faster responses being associated with more accurate ones. There are no correlations between speed and accuracy within and between the visual fields either. Remember that in Study 1 (Face Recognition no Speech), there was a positive correlation between speed and accuracy within the RVF and, that in Study 2 (Face Recognition with Related Speech), there was a positive correlation between speed in the RVF and accuracy in the LVF.

Subjects were again divided based upon the difference between the mean reaction time for correct responses to faces in the LVF and the mean reaction time for correct responses to faces in the RVF. Fifteen subjects were faster in the RVF and ten subjects were faster in the LVF. This was different from the distribution in Study 1, where most subjects (19 of 25) were faster in the LVF. A Chi Square comparison of the distribution of subjects found significant

differences between Study 1 and the current study ($\chi^2=6.65$, $df=1$, $p<.01$). See Table 8. The group which was faster in the LVF recognized a mean of 68.1 faces correctly while the group which was faster in the RVF recognized a mean of 61.3 faces correctly. This difference of 6.8 faces is in the opposite direction from what was observed in Study 1, where the RVF ADV group recognized more faces correctly, but the difference is not significant ($F(1,23)=1.43$, $p=.25$).

TABLE 8
STUDY 1 - STUDY 3 COMPARED

INDIVIDUALS GROUPED BY PROCESSING SPEED ADVANTAGE
FASTER IN LVF (LVF ADV) VERSUS FASTER IN RVF (RVF ADV)

ACCURACY IN LVF AND RVF ON FACE RECOGNITION
NUMBER OF FACES CORRECTLY RECOGNIZED

	<u>N</u>	<u>LVF</u> MEAN SD	<u>RVF</u> MEAN SD	<u>TOTAL</u> MEAN SD
<u>STUDY 1</u>				
LVF ADV	19	33.1 (9.0)	31.7 (8.7)	64.8 (16.6)
RVF ADV	6	38.3 (11.6)	44.0 (15.0)	82.3 (23.2)
<u>STUDY 2</u>				
LVF ADV	13	32.7 (8.1)	34.2 (6.6)	66.9 (13.7)
RVF ADV	12	33.3 (5.0)	31.5 (7.1)	64.8 (11.6)
<u>STUDY 3</u>				
LVF ADV	10	35.4 (11.2)	32.7 (11.0)	68.1 (20.1)
RVF ADV	15	30.8 (5.6)	30.5 (5.1)	61.3 (8.0)

FACE RECOGNITION REACTION TIME IN LVF AND RVF
REACTION TIMES FOR CORRECT RESPONSES
(IN MSEC)

<u>STUDY</u>	<u>N</u>	<u>LVF</u> MEAN SD	<u>RVF</u> MEAN SD	<u>TOTAL</u> MEAN SD
<u>STUDY 1</u>				
LVF ADV	19	4129 (1182)	4731 (1399)	4430 (1225)
RVF ADV	6	4476 (1575)	4096 (1670)	4286 (1618)
<u>STUDY 2</u>				
LVF ADV	13	4589 (1338)	5243 (1997)	4916 (1608)
RVF ADV	12	4749 (1278)	4302 (1088)	4525 (1172)
<u>STUDY 3</u>				
LVF ADV	10	4427 (1109)	5096 (1691)	4761 (1361)
RVF ADV	15	4310 (796)	3894 (756)	4102 (759)

HOW WELL DO PARTICIPANTS DO TWO THINGS AT ONCE?
STUDY 3 - FACE RECOGNITION AND UNRELATED INCIDENTAL SPEECH

AUDITORY RECOGNITION SESSION

INTRODUCTION

The rationale and procedure for the auditory recognition session was identical to that for Study 2.

RESULTS

ACCURACY AND SPEED ON DELAYED SPEECH RECOGNITION

Performance on the delayed speech recognition session is summarized in Table 9. Subjects correctly recognized 84.6% of the speech stimuli, which is better than the 50% chance level. As in Study 2, the number correct for each word type was expressed as a percentage (due to the fact that there were differing numbers of stimuli in each category) and arcsine transformations were applied. An ANOVA with repeated measures on the four categories of speech stimuli revealed a main effect for word type ($F(3,72)=24.76, p<.001$). A similar analysis of the reaction time data, also showed a main effect of word type

($F(3,72)=7.95$, $p<.001$). As in Study 2, significant word type differences are largely consistent based upon both reaction time and percent correct indicating that the category of new voice/new word was the easiest.

Comparisons between face recognition with related speech (Study 2) and face recognition with unrelated speech (Study 3) were made utilizing a two by four repeated measure ANOVA. There were no differences between the studies based upon either accuracy ($F(1,48)=1.02$, $p=.32$) or reaction time ($F(1,48)=.92$, $p=.35$).

TABLE 9
STUDY 2 and STUDY 3 COMPARED

PERFORMANCE ON DELAYED SPEECH RECOGNITION

PERCENT CORRECT BY WORD TYPE

<u>STUDY</u>	<u>N</u>	<u>OLD VOICE</u> <u>NEW WORD</u>	<u>OLD VOICE</u> <u>OLD WORD</u>	<u>NEW VOICE</u> <u>NEW WORD</u>	<u>NEW VOICE</u> <u>OLD WORD</u>	<u>** TOTAL</u> <u>% CORRECT</u>
		MEAN (SD)	MEAN (SD)	MEAN (SD)	MEAN (SD)	MEAN (SD)
2	25	90.5 (12.1)	74.2 (12.0)	96.5 (10.5)	84.0 (20.6)	82.2 (7.0)
3	25	92.0 (10.8)	76.2 (13.5)	99.5 (2.5)	87.5 (18.0)	84.6 (6.6)

REACTION TIME FOR CORRECT RESPONSES BY WORD TYPE
(IN MSEC)

<u>STUDY</u>	<u>N</u>	<u>OLD VOICE</u> <u>NEW WORD</u>	<u>OLD VOICE</u> <u>OLD WORD</u>	<u>NEW VOICE</u> <u>NEW WORD</u>	<u>NEW VOICE</u> <u>OLD WORD</u>	<u>TOTAL</u>
		MEAN (SD)	MEAN (SD)	MEAN (SD)	MEAN (SD)	MEAN (SD)
2	25	3065 (1134)	3322 (998)	3024 (919)	4022 (2613)	3358 (1210)
3	25	2983 (883)	3382 (765)	2577 (677)	3398 (1374)	3085 (755)

** The category of OLD VOICE OLD WORD had 24 target; whereas the other categories each had only 8 targets. Thus the total % correct is not the mean of each of the category percentages

STUDY 3
RESULTS
RELATIONSHIP BETWEEN FACE RECOGNITION AND DELAYED SPEECH
RECOGNITION

Since performance on delayed speech recognition was above chance, analyses were performed to examine the relationship between accuracy on face recognition and accuracy on speech recognition. Pearson correlations were calculated between mean number of faces correctly recognized in the left and in the right visual fields and total correct for the entire auditory session and for the largest single word type - old voice/old word. A positive correlation between faces correctly recognized in the RVF and total speech performance only approached significance ($r(25) = .37$, $p < .07$). There were no significant correlations between mean number correct in the left or in the right visual field and total correct in the category of old voice old word. Thus, there is only a very weak suggestion of a complementary process between speech and face recognition for the RVF and no such association in the LVF, where the correlation between face accuracy and total speech accuracy is negative ($r(25) = -.12$). There is also no indication of a late developing relationship between face and speech performance as there had been in Study 2.

Thus the relationship between face and speech

performance in the current study, is different from what was observed in Study 2. In Study 2, good performance on face recognition in both the LVF and the RVF predicted good performance on total speech recognition and, even more strongly, predicted good performance in the category of old voice/old word.

In an attempt to look at possible individual differences in relation to the negative correlation between RH accuracy on faces and speech accuracy, Pearson correlations were calculated separately for the processing speed advantage groups. These are reported in Table 10. The LVF ADV group exhibited non-significant positive correlations between face and speech processing. Conversely, the RVF ADV group exhibited negative correlations, but only for responses in the LVF (LVF correct/total auditory: $r(15) = -.49, p < .07$; LVF correct/old voice old word: $r(15) = -.48, p < .08$). The relationship between face and speech accuracy in the LVF for the RVF ADV group is strikingly different in Studies 3 and 2. When faces and speech were related, as in Study 2, the correlation was positive ($r(12) = .40$). In Study 3 where faces and speech were unrelated, the correlation was negative ($r(15) = -.49$). These correlations are significantly different from one another ($z = 2.20, p < .05$) (Bruning & Kintz, 1977).

In Study 2, one of the most interesting findings was that those subjects who responded more quickly to faces presented to the RVF (LH) also performed better on speech recognition, especially in the categories of old voice/new word and new voice/new word. In the current study, this was not the case ($F(1,23)=1.43$, $p=.43$); although, the non-significant trend was in the same direction with the RVF ADV group getting 85.7% correct and the LVF ADV group getting 82.9% correct. The difference in performance of these groups between the two studies did not produce a significant group by study interaction ($F(1,46)=1.46$, $p=.24$). See Table 11.

TABLE 10
STUDY 2 AND STUDY 3 COMPARED

PEARSON CORRELATIONS BETWEEN FACE AND SPEECH RECOGNITION
ACCURACY
FOR LVF ADV AND RVF ADV GROUPS
SPEECH PERFORMANCE

	TOTAL AUDITORY	OLD VOICE OLD WORD
<u>STUDY 2</u>		
LVF ADV		
LVF	$r(13) = .36$	$r(13) = .51!$
RVF	$r(13) = .71^{**}$	$r(13) = .57^{*}$
RVF ADV		
LVF	$r(12) = .40$	$r(12) = .42$
RVF	$r(12) = .40$	$r(12) = .56!$
<u>STUDY 3</u>		
LVF ADV		
LVF	$r(10) = .20$	$r(10) = .10$
RVF	$r(10) = .51$	$r(10) = .43$
RVF ADV		
LVF	$r(15) = -.49!$	$r(15) = -.48!$
RVF	$r(15) = .33$	$r(15) = .13$

! $p < .10$
* $p < .05$
** $p < .01$

TABLE 11
STUDY 2 AND STUDY 3 COMPARED

INDIVIDUALS GROUPED BY PROCESSING SPEED ADVANTAGE
FASTER IN LVF (LVF ADV) VERSUS FASTER IN RVF (RVF ADV)

PERCENT CORRECT BY WORD TYPE ON DELAYED SPEECH
RECOGNITION
(IN MSEC)

<u>STUDY</u>	<u>N</u>	<u>OLD VOICE</u> <u>NEW WORD</u> MEAN (SD)	<u>OLD VOICE</u> <u>OLD WORD</u> MEAN (SD)	<u>NEW VOICE</u> <u>NEW WORD</u> MEAN (SD)	<u>NEW VOICE</u> <u>OLD WORD</u> MEAN (SD)	<u>**TOTAL</u> MEAN (SD)
<u>STUDY 2</u>						
LVF	13	84.6 (13.6)	74.4 (10.9)	93.3 (14.1)	79.8 (23.7)	80.1 (6.8)
ADV						
RVF	12	96.9 (5.7)	74.0 (13.7)	100.0 (000)	82.0 (16.4)	84.5 (6.6)
ADV						
<u>STUDY 3</u>						
LVF	10	91.3 (8.4)	74.6 (16.0)	100.0 (000)	82.5 (25.1)	82.9 (7.3)
ADV						
RVF	15	92.5 (12.3)	77.2 (12.0)	99.2 (3.2)	90.8 (11.0)	85.7 (6.1)
ADV						

** The category of OLD VOICE OLD WORD had 24 target; whereas the other categories each had only 8 targets. Thus the total % correct is not the mean of each of the category percentages

STUDY 3
FURTHER SPECULATIONS CONCERNING A POSSIBLE TRADE OFF IN
PROCESSING BETWEEN SPEECH AND FACE

The lack of a strong association between speech and face processing performance raises an interesting possibility in terms of what might be happening during the simultaneous presentation of unrelated faces and speech, particularly in the RH. It suggests that in the RH, in the absence of a relationship between the faces and speech, there is a tendency to divide attention between the two and thus to do better in either face recognition or speech recognition rather than both. It seems that this might especially be true for the 15 individuals in the RVF ADV group where the correlation is stronger ($r(15) = -.49$, $p < .08$).

Based upon the fact that this is a descriptive study, a look at yet another post-hoc division of subjects will be undertaken in an attempt to get a further view into this suggestion. While in a descriptive study it would be sufficient to simply look at the descriptive statistics involved in such a division of subjects, inferential statistics will be applied in an attempt to eliminate differences that are totally meaningless. However, it is clearly understood that such application of multiple analyses increases the risk of Type I errors and would be

unacceptable if hypothesis testing rather than description were involved.

If a trade-off between speech and face processing were occurring in Study 3, one would expect that those who did well during the delayed speech recognition, would not have done so well during face recognition processing. If the process is complementary, as was suggested by the correlational data for the related speech and face processing in Study 2, one would expect that those who do well on the speech recognition would also do well on face recognition. Subjects were divided based upon whether they performed above or below the median on speech recognition. Performance for this division of subjects is summarized in Table 12. The median score for both Studies 2 and 3 was 40. This did not result in an even distribution of subjects into high and low performers because for each study there were numerous subjects who scored exactly 40.

In Study 3, the total number of faces correctly recognized between high and low performers on speech recognition was nearly the same. Looking at the mean number of faces correctly recognized in the LVF (RH) reveals that those who did less well on the auditory session did better on face recognition in the LVF than those who did well during the auditory session. This is reflected in a significant group by visual field interaction ($F(1,23)=6.17$,

$p < .03$). Thus, as was hinted at by the (non-significant) negative correlation between LVF (RH) performance on the faces and speech recognition performance, those who do worse at speech recognition do better at face recognition, but only in the LVF (RH). In terms of speed of response, those who do worse on speech recognition, respond more quickly to faces in both visual fields, but this difference only approaches significance based upon a two by two repeated measures ANOVA ($F(1,23)=3.61$, $p < .08$). This analysis thus provides further suggestion of some sort of trade off in processing between attention to faces and attention to speech, but only in the LVF (RH).

These patterns are different from those observed in Study 2 (as would be expected based upon the significant positive correlations between face and speech performance in both visual fields for that study). See Table 12. In Study 2, there is a non-significant trend for those who do better during the auditory session, the high speech performers, to also have correctly recognized more faces in both visual fields during the face recognition task ($F(1,23)=1.39$, $p = .26$). Contrary to high and low speech performers in Study 3, there is no tendency for low speech performers in Study 2 to respond more quickly to faces.

Subjects were further divided into approximately the top quartile (92% or better correctness rate) and bottom

quartile (79% or worse correctness rate) in performance on speech recognition to see whether the patterns would hold. See Table 13 for a summary of results. The new division of subjects maintains a difference in patterns of performance between Studies 1 and 2. In Study 2, the complementary relationship between face and speech recognition performance, i.e. good at both processes or poor at both, is maintained and sharpened with this division; so that, for number of faces correctly recognized, the effect of group now approaches significance ($F(1,9)=4.51$, $p=.06$). There are still no significant effects in relation to speed of response to faces.

For Study 3, this division of subjects increases the difference in face recognition performance between the RVF (LH) and LVF (RH) for subjects with low speech performance with 26.7 faces correctly recognized in the RVF and 35.3 faces correctly recognized in the LVF. The division simultaneously diminishes differences between high and low speech performers in the LVF (RH). Now, in the LVF (RH), the high and low speech performers both do equally well on faces (35.2 and 35.3 faces correct respectively), but they perform quite differently in the RVF (LH) (hi speech: 36.2 low speech: 26.7). The group by visual field interaction, however, is not significant ($F(1,11)=3.76$, $p<.08$). There is no longer evidence of a difference in speed of response to

faces between the groups ($F(1,20)=.37$, $p=.55$). The high face recognition performance in the LVF (RH) of subjects in the bottom quartile, based upon speech performance, is interesting when compared either to the performance in the RVF (LH) of the low speech performers in this study or when compared to the LVF (RH) performance of the low speech performers in Study 2.

TABLE 12
STUDY 2 AND STUDY 3 COMPARED

INDIVIDUALS GROUPED BY SPEECH RECOGNITION ACCURACY
ABOVE THE MEDIAN (HI SPEECH PERFORMERS)
AND BELOW THE MEDIAN (LO SPEECH PERFORMERS)

ACCURACY IN LVF AND RVF ON FACE RECOGNITION
NUMBER OF FACES CORRECTLY RECOGNIZED

	<u>N</u>	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
<u>STUDY 2</u>							
HI SPEECH	10	34.4	(6.0)	35.1	(6.7)	69.5	(11.8)
LO SPEECH	15	32.1	(7.0)	31.5	(6.8)	63.5	(12.8)
<u>STUDY 3</u>							
HI SPEECH	14	31.0	(8.2)	32.9	(8.9)	63.9	(15.7)
LO SPEECH	11	34.7	(8.6)	29.4	(6.1)	64.1	(12.6)

FACE RECOGNITION REACTION TIME IN LVF AND RVF
REACTION TIMES ON CORRECT RESPONSES
(IN MSEC)

	<u>N</u>	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
<u>STUDY 2</u>							
HI SPEECH	10	4781	(1212)	4540	(1026)	4661	(1090)
LO SPEECH	15	4588	(1367)	4959	(1998)	4774	(1610)
<u>STUDY 3</u>							
HI SPEECH	14	4690	(919)	4724	(1627)	4707	(1223)
LO SPEECH	11	3932	(743)	3930	(642)	3931	(646)

TABLE 13
STUDY 2 and STUDY 3 COMPARED

INDIVIDUALS GROUPED BY SPEECH RECOGNITION ACCURACY
TOP AND BOTTOM QUARTILE

ACCURACY IN LVF AND RVF ON FACE RECOGNITION
NUMBER OF FACES CORRECTLY RECOGNIZED

	<u>N</u>	<u>LVF</u> MEAN SD	<u>RVF</u> MEAN SD	<u>TOTAL</u> MEAN SD
<u>STUDY 2</u>				
HI SPEECH	5	36.2 (6.2)	34.4 (6.2)	70.6 (12.3)
LO SPEECH	6	29.7 (4.8)	27.8 (4.5)	57.5 (8.1)
<u>STUDY 3</u>				
HI SPEECH	6	35.2 (10.0)	36.2 (12.0)	71.3 (19.8)
LO SPEECH	7	35.3 (10.0)	26.7 (5.1)	62.0 (13.5)

FACE RECOGNITION REACTION TIME IN LVF AND RVF
REACTION TIMES ON CORRECT RESPONSES
(IN MSEC)

	<u>N</u>	<u>LVF</u> MEAN SD	<u>RVF</u> MEAN SD	<u>TOTAL</u> MEAN SD
<u>STUDY 2</u>				
HI SPEECH	5	4956 (1488)	4607 (1113)	4782 (1294)
LO SPEECH	6	4620 (1050)	4698 (1182)	4659 (1073)
<u>STUDY 3</u>				
HI SPEECH	6	4406 (1205)	4147 (1205)	4277 (916)
LO SPEECH	7	3838 (718)	3980 (654)	3909 (655)

STUDY 3
SUMMARY OF OBSERVATIONS

FACE PROCESSING

- * **No support for multimodal facilitation of performance having occurred in Study 2 as a result of related faces and speech. No evidence for overall performance differences in either speed or accuracy compared to Study 1 or Study 2.**

- * **No evidence for performance differences between the hemispheres in either speed or accuracy, or of a difference in the distribution of subjects into hemispheric advantage groups. As in Study 2, no evidence of a RH ADV for faces in the presence of speech.**

- * **No correlations between speed and accuracy on face recognition. (This contrasts with Study 1 where there was a positive correlation between LH speed and LH accuracy and Study 2 where there was a positive correlation between LH speed and RH accuracy.)**

STUDY 3
SUMMARY OF OBSERVATIONS

SPEECH PROCESSING

- * Subjects continue to do two things at once despite the incidental presentation of speech. Accuracy on the auditory session well above chance (84.6%) with correctness level for new voice/new word at 99.5%.
- * There continues to be a main effect for word type with indications that word is still more salient than voice and with no evidence of a difference in performance between Studies 2 and 3.
(percent correct: $F(3,72)=24.76$, $p<.001$)
(reaction time: $F(3,72)=7.95$, $P<.001$)
- * Subjects who were faster responding correctly to faces in the LH do not correctly recognize a higher percentage of speech stimuli as they had done in Study 2 (although the non-significant trend was in the same direction).
- * There are no longer strong positive correlations between accuracy on face and accuracy on speech recognition
- * For the RH only there are some hints of a trade off in attention between faces and speech (observations suggesting this include the face recognition accuracy of high and low speech performers (hi/low speech group by VF interaction on face recognition: $F(1,23)=6.17$, $p<.03$) and negative correlations between RH face recognition accuracy and speech recognition).

STUDY 3 FACE RECOGNITION WITH UNRELATED SPEECH

DISCUSSION

Two main questions were asked at the outset of this study. One was related to multimodal facilitation of performance and the other to whether specific patterns of hemispheric advantage occurred due to the relatedness of faces and speech. The first of these questions was answered unequivocally. The thought prior to Study 3 was that even though performance was not better in Study 2, where speech and faces were related, than in Study 1, it might have been still worse in Study 2 without that relationship. In Study 3 the redundancy between face and speech was removed, but face recognition performance did not decline. Thus, it was clearly not the case that face performance in Study 2 was in any way improved by the association between face and speech. Subjects performed equally well when processing non-related concurrent speech as when processing related concurrent speech.

Even though there were no performance differences in either face or speech recognition, due to the lack of relationship between the two, a number of associations between face performance and the hemispheres and between

face and speech performance seem to have been altered. Perhaps these are more subtle manifestations of differences in cognition due to processing unrelated as opposed to related faces and speech. Generally, certain processes that had been coupled previously seem to have become uncoupled. One disassociation that occurred is in the connection between speed and accuracy in face processing. The other is between accuracy in face processing and accuracy in speech recognition processing.

In both Study 1 and Study 2, accuracy and speed on face recognition were positively correlated, if in somewhat different ways. In Study 1, speed in the LH was associated with accuracy in the LH and in Study 2 speed in the LH was associated with accuracy in the RH. In the concurrent processing of faces and unrelated speech, there are no significant relationships between the two. One possible direction for an explanation of this observation is related to the idea that a positive association between speed and accuracy might be indicative of a very efficient process, perhaps one that is highly rehearsed or highly routinized. Encountering still faces or a face with the same voice are examples of situations that might tend to "pull up" routinized processes. On the other hand, dealing with a single face that is associated with a continuously different

voice may be atypical and less likely to engage a well rehearsed, highly efficient process.

The weakening of the association of face and speech performance is the second uncoupling and may be a more direct reflection of the lack of relationship between voice/word and face. In Study 2, where the face and speech were related, there were predominantly significant positive correlations between face recognition accuracy in both visual fields and total auditory performance, as well as performance in the category of old voice/old word. In the current study, only face recognition performance in the RVF (LH) was weakly ($r(25) = .37$, $p < .10$) associated with total auditory performance. No other relationships even approach significance. Additionally, those between the LVF (RH) face performance and auditory recognition were negative. For the RVF ADV group, the negative correlation between right hemisphere face performance and speech recognition is more pronounced ($r(15) = -.49$, $p < .07$) and is significantly different from the positive correlation observed for this group in the RH when speech and faces were related. It seems most likely that this disassociation is a manifestation of the unrelatedness of the faces and speech. When related, even if overall performance was not enhanced, attending to both and to their relationship could tie performance in both modalities together. When no

relationship between the two exists it may become easier to attend to one more than the other.

While there is a general weakening of the association of face and speech performance, this trend is particularly strong in regard to the RH. In Study 2 there is a positive association between face and speech performance in the RH, but in the current study there is some indication of a negative one. This suggests a difference between the hemispheres in how they respond to the relatedness of concurrent auditory and visual information. The difference in patterns of association between the studies also argues against the positive correlation between face and speech recognition performance in Study 2 being interpreted simply as the product of exceptionally high performing and exceptionally low performing individuals. If this idea were correct, there is no reason that the data from Study 3 should not manifest the same pattern.

Perhaps the LH, which is most likely more involved in processing speech, especially given the seemingly greater saliency of word, is attentively tuned to the presence of any speech, whether related to the visual stimuli or not. For the RH, when there is no relationship to be perceived, the processes are more likely to divide attention, generating a trade off between face and speech processing. Perhaps the RH is specialized for the processing of a

connection between speech and face and is disengaged and more likely to attend to the face alone when no connection is available.

The division of subjects based upon performance on speech recognition casts more light onto this discussion. If there is a trade off in attention in Study 3, especially in the RH, one would expect that high performers on the auditory session should be low performers on face recognition and vice versa. Based upon similar reasoning, in Study 2 where speech is related to faces, those who do well on the auditory recognition ought also to do well on face recognition. In Study 2, the division based both upon using the median and, even more so, upon using the upper and lower quartiles for speech recognition, clearly reflects a pattern of doing well on both faces and speech or of doing poorly on both. As discussed earlier, this could be attributed to the prowess of the subjects, but the fact that patterns of performance resulting from these divisions are not the same for Study 3 further mitigates against this interpretation and points more toward the relatedness of face and speech as at least part of the underlying reason.

For Study 3, the division based upon a median split provides some support to the idea of a trade off in attention between faces and speech. Reaction time data show high auditory performers are slower on face processing

responses in both visual fields. Low auditory performers are faster at face processing, possibly indicating less attention directed to, or less processing of, speech. The number of faces correctly recognized adds some support to the idea of a trade off, but only in terms of responses in the RH. The number of faces correctly recognized in the RH for low auditory performers is higher than for high auditory performers.

The quartile results for Study 3 do not present the same pattern, but the observed pattern is still different from that for low auditory performers in Study 2, and thus continues to lend substantiation to the idea that the patterns observed are related to the conditions of the experiment rather than to a general division between high and low performing individuals. Those most accurate at speech recognition are also good at faces and do not really appear to be different from the high speech performers in Study 2. The low speech performers, on the other hand, are poor at face recognition in the LH (RVF) and maintain high performance on face recognition in the RH (LVF). In this latter regard they are different from the bottom quartile of speech performers in Study 2. The central question that is raised is why performance in the RH (LVF) is different, in the unrelated face voice concurrence, from performance in the LH (RVF).

Some general results of Study 3 should be noted prior to concluding this discussion. Consistent with Study 2, there is no longer evidence for either the overall RH processing speed advantage for face recognition or for the emergence of a highly proficient LH ADV, both of which were observed when faces were processed alone. Just as in Study 2, the distribution of subjects also does not favor those with a RH processing speed ADV and is different from the distribution in Study 1. In this study, compared to Study 1, there was a non-significant trend for RH (LVF) responses to slow down by 144 msec and for LH (RVF) responses to speed up by 205 msec. Thus, these data lend more support to a priming explanation for the disappearance of the RH ADV (See Discussion of Study 2 for more details) than did the data from Study 2. It seems, then that the mere presence of speech, whether related to the faces or not related, is enough to disrupt the patterns of lateralization favoring the RH. Of course, a logical next question is whether speech is required at all, or whether some other auditory process could also disrupt this seemingly fragile RH advantage for faces.

CHAPTER 5

IS THE SPEECH FACE COMBINATION SPECIAL? DOES THE PROFICIENCY OF PROCESSING INCIDENTAL SPEECH, AND THE PATTERNS OF HEMISPHERIC INVOLVEMENT, OBSERVED IN PREVIOUS STUDIES PERTAIN WHEN THE CONCURRENT PROCESSING DOES NOT INVOLVE A FACE?

WHEN IS A FACE NOT A FACE? WHEN IT IS INVERTED.

STUDY 4 - INVERTED FACE RECOGNITION NO SPEECH

STUDY 5 - INVERTED FACE RECOGNITION RELATED SPEECH

INTRODUCTION

One interesting observation in the first set of studies was the lack of decline in face recognition performance despite the increased processing load resulting from the simultaneous presentation of speech. This is especially interesting given the fact that the speech was incidentally presented and that subjects performed very well on the surprise speech identification. One possible explanation for these results is that they are due to the ecological importance of simultaneously processing faces and speech. The existence of this special connection was one of the starting points for these studies.

One way to explore this possible explanation would be to present non-face stimuli with speech; another way would be to present faces with non-speech stimuli. Either of these approaches would also allow consideration of which other observations that were made were unique to the face speech combination. Either way, an attempt would have to be

made to find equally complex stimuli to substitute for the faces or speech. In an effort to look at this question, while presenting equally complex stimuli, concurrent presentation of inverted faces and speech was considered. Clearly, in real life, we do not, with any regularity, process upside down faces with speech. Concurrent processing of inverted faces and speech is not ecologically relevant, and thus would not be expected to involve any particular expertise, such as the expertise that might be related to the ability to co-process faces and incidentally presented speech. In addition to this intuitive approach to suggest the use of upside down faces, there is a long history of research in the face perception literature that explores processing of inverted faces.

Yin first began testing the proficiency of upside down face recognition in 1969 in attempts to explore the "special" nature of face perception. He found that faces, when inverted, became the most difficult category of objects to recognize rather than the easiest (Ellis & Young, 1989). Inversion has typically resulted in a 30% decline in performance compared to 10% for other types of objects (Cohen-Levine, 1989). These observations spurred a search for some other class of mono-oriented objects which would yield similar performance decrements. Houses, airplanes, automobiles, landscapes and dogs are among those that have

been included in these attempts at replication, none of which proved unquestionably successful. In terms of hemispheric laterality and face inversion, there is evidence that prosopagnosics are not generally impaired at recognizing inverted faces which implies that the same areas of the brain are not involved in processing upright faces and inverted faces (Farah, 1995). Among normals there is also evidence that the RH is more impaired by inversion than the LH (see Ellis & Young, 1989, for review). Thus, with a substantial body of research upon which to rest, the current study undertook presenting inverted faces to explore whether the findings related to upright faces and incidental speech were due to this special combination.

STUDY 4 METHOD

SUBJECTS

The subjects were recruited and screened similarly to Studies 1, 2 and 3. There was one difference. In the first 3 studies, subjects were recruited from psychology classes as unpaid volunteers. In this study, the subjects participated as part of the course requirement. They were 22 right handed males and females (3 males and 19 females) with self reported normal hearing and with a mean age of 22.0 (SD=4.2) years. The data from 2 additional subjects were dropped because of the following: misunderstood directions - 1; inordinately long reaction times - 1

VISUAL STIMULI

The faces were inverted 180 degrees using computer software. Pilot tests were then run to produce a set of stimuli which would result in similar error rates to those for the upright faces. This was done to avoid a confound based upon ease of processing. Since the inverted faces are known to be more difficult to process, if the tasks had not first been equated for difficulty, any further performance

alterations could be attributed to the complexity of processing as opposed to the ecologically rare combination of inverted faces and speech. In order to do this, however, a number of alterations in the experimental procedure were required. It must be kept in mind that while avoiding one known confound, these alterations make the upright and inverted studies different enough to make direct comparisons between them somewhat tenuous.

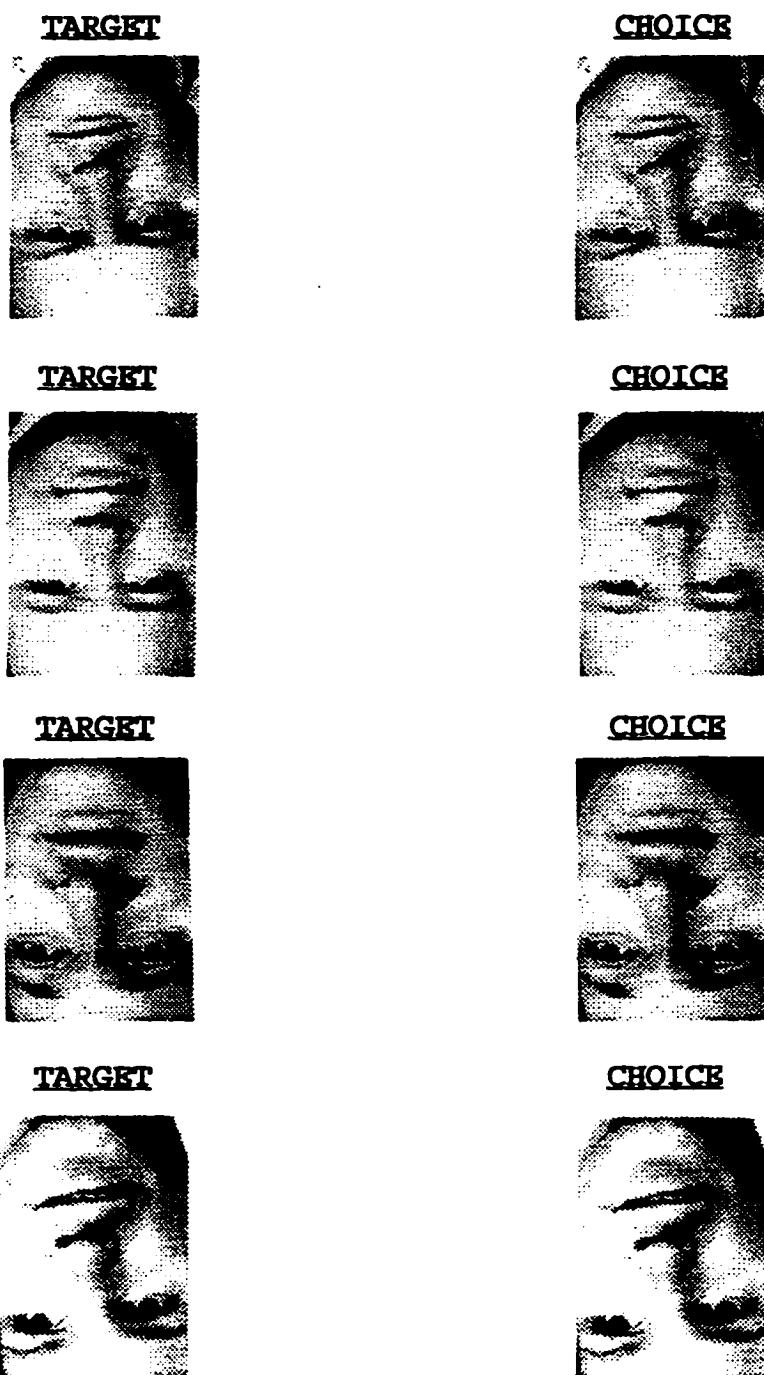
Initially, five pilot subjects were run under precisely the same conditions as Study 1, except that the faces were inverted. The correctness level for these subjects was 35.4%. This is approximately a 26% reduction from the 47.9% correctness level observed for Study 1, and seems in line with the typically reported 30% reduction for the inversion effect. Pilot data were subsequently collected at 110 msec duration, and when that was unsuccessful at achieving appropriate correctness rates, at 175 msec duration. Unfortunately, the correctness level was still not comparable to the Study 1 level. Since the upper exposure limit of 200-250 msec for tachistoscopic presentation was being reached, the exposure limit under which subjects are not likely to make eye movements, an additional alteration was made. The task was made still easier by using exactly the same photograph for target and choice rather than an altered view of the same individual for the choice. Thus,

the target faces as seen in Figure 8 were also used for the choices. Finally, with the exposure duration at 175 msec rather than 65 msec, and targets and choices as the same photographs rather than altered views, the correctness level for 6 pilot subjects was 50%. This was considered close enough to the level observed in Study 1 (upright faces no speech) to proceed. The rather frustrating manipulations required in this process were clear substantiations (unneeded, of course) of the powerfully detrimental effects of inversion on the face recognition process. While considering the two studies involving inverted faces, one should not lose sight of the fact that extensive manipulations were made to the stimuli in order to equate task difficulty.

PROCEDURE

The procedure was identical to the procedure in Study 1.

FIGURE 8

STUDY 4
INVERTED FACE STIMULI

STUDY 4
INVERTED FACE RECOGNITION RESULTS
ACCURACY AND REACTION TIMES IN LVF AND RVF ON FACE
RECOGNITION

ACCURACY

Subjects correctly recognized a mean of 69.9 (SD=14) inverted faces for an overall correctness level of 48.5%. Thus the 110 msec increase in exposure duration and the use of the same photographs for targets and choices were successful manipulations in creating similar performance levels between the upright and inverted conditions. Subjects correctly recognized a mean of 34.6 (SD=7.9) inverted faces in the LVF and a mean of 35.3 (SD=7.0) inverted faces in the RVF. Just as in all of the previous studies, there is no evidence of a difference between the visual fields in the number of faces correctly recognized ($F(1,21)=.52$, $p=.49$).

There was a significant block effect ($F(5,105)=8.12$, $p<.001$) and a significant linear trend ($t=5.75$, $p<.001$) with the percent of inverted faces correctly recognized increasing from 41.3% in Block 1 to 57.1% in Block 6. (Block data are in Appendix A, Table A11.)

REACTION TIME/SPEED

As with the data for all prior studies, a reciprocal square root transformation was applied to the mean total correct reaction time data to correct for lack of homogeneity of the variances. (Analysis based upon the non-transformed measures is in Appendix A, Table A1). The raw data are presented in Table 14.

The mean reaction time for correct responses was 4625 msec (SD=1042) overall, 4557 msec (SD=1168) in the LVF and 4693 (SD=959) in the RVF. The 136 msec difference, favoring the LVF approached significance, as determined by a repeated measures ANOVA ($F(1,21)=3.75$, $p<.07$). The mean correct reaction time in the inverted study was 229 msec slower than the mean correct reaction time in the study of upright faces without speech, but when the data from these two studies were directly compared, a somewhat questionable analysis given the differences between the studies, this difference was not significant ($F(1,45)=1.12$, $p=.30$).

Reaction times were analyzed across time as divided into blocks. Based upon a 2 by 6 repeated measures ANOVA, there was a significant block effect ($F(1,105)=6.38$, $df<.01$), but no evidence of a left right by block interaction ($F(1,105)=.95$, $p=.46$). There was also a

significant linear trend ($t=-3.70$, $p<.001$) with reaction times decreasing across blocks. (Block data are in Appendix A, Table A12.)

The mean incorrect reaction time was 5257 msec (SD=1408) overall, 5193 msec (SD=1390) in the LVF and 5321 msec (SD=1576) in the RVF. The mean correct reaction times were significantly faster than the mean incorrect reaction times ($F(1,21)=18.36$, $p<.001$). The difference of 128 msec between the LVF and RVF was not significant ($F(1,21)=.16$, $p=.71$). See Appendix A, Table A13 for data.

TABLE 14
STUDY 1 - STUDY 4 COMPARED
FACE RECOGNITION REACTION TIME IN LVF AND RVF
REACTION TIMES FOR CORRECT RESPONSES
(IN MSEC)

<u>STUDY</u>	<u>N</u>	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
STUDY 1	25	4213	(1260)	4579	(1458)	4396	(1294)
STUDY 2	25	4666	(1285)	4791	(1663)	4729	(1401)
STUDY 3	25	4357	(913)	4375	(1329)	4366	(1067)
STUDY 4	22	4557	(1168)	4693	(959)	4625	(1042)

STUDY 4
RESULTS
RELATIONSHIP BETWEEN SPEED AND ACCURACY ON INVERTED FACE
RECOGNITION

Contrary to Study 1 (Upright faces no speech) where LVF (RH) speed and accuracy were positively correlated, there seem to be no relationships between speed and accuracy in the current study. All of the correlations calculated yield correlation coefficients remarkably near zero. Thus, no highly complementary processing nor any processing which involves a trade-off between speed and accuracy is suggested. The difference between the correlation of LH speed and accuracy in Study 1 ($r(25) = -.52$) and the corresponding correlation in this study ($r(22) = .07$) is significant ($z = 2.06$, $p < .05$) (Bruning & Kintz, 1977).

In order to highlight any patterns of individual differences in this processing and to remain consistent with previous studies, subjects were divided based upon relative processing speed. Fifteen subjects were faster in their responses to faces in the LVF and only seven were faster in their responses to faces in the RVF. This breakdown of subjects is similar to that which occurred in Study 1, as can be seen in Table 15, where 19 subjects were relatively faster in the LVF and 6 were relatively faster in the RVF. Study 1 also involved visual processing without concurrent

speech. In the case of Study 1, the distribution of subjects differed significantly from what would have been expected by chance; however, in the current study a Chi square analysis only approached significance ($\chi^2=2.91$, $df=1$, $p<.09$).

The RVF ADV group recognized a mean of 76.1 inverted faces correctly and the LVF ADV group recognized a mean of 67.0 inverted faces correctly. This difference of 9.1 faces was not significant ($df=1,20$; $F=2.11$; $p=.17$). However the non-significant trend was in the same direction as it was in Study 1, i.e. with the RVF ADV group performing better than the LVF ADV group.

TABLE 15
STUDY 1 - STUDY 4 COMPARED

INDIVIDUALS GROUPED BY PROCESSING SPEED ADVANTAGE
FASTER IN LVF (LVF ADV) VERSUS FASTER IN RVF (RVF ADV)

ACCURACY IN LVF AND RVF ON FACE RECOGNITION
MEAN NUMBER OF FACES CORRECTLY RECOGNIZED

	N	<u>LVF</u> MEAN SD	<u>RVF</u> MEAN SD	<u>TOTAL</u> MEAN SD
<u>STUDY 1</u>				
LVF ADV	19	33.1 (9.0)	31.7 (8.7)	64.8 (16.6)
RVF ADV	6	38.3 (11.6)	44.0 (15.0)	82.3 (23.2)
<u>STUDY 2</u>				
LVF ADV	13	32.7 (8.1)	34.2 (6.6)	66.9 (13.7)
RVF ADV	12	33.3 (5.0)	31.5 (7.1)	64.8 (11.6)
<u>STUDY 3</u>				
LVF ADV	10	35.4 (11.2)	32.7 (11.0)	68.1 (20.1)
RVF ADV	15	30.8 (5.6)	30.5 (5.1)	61.3 (8.0)
<u>STUDY 4</u>				
LVF ADV	15	32.9 (6.3)	34.1 (5.5)	67.0 (11.1)
RVF ADV	7	38.1 (10.3)	38.0 (9.4)	76.1 (18.5)

STUDY 4
SUMMARY OF OBSERVATIONS

- * RH correct responses to inverted faces approached being significantly faster than LH responses. This was similar to the study of upright faces without speech (Study 1) where the difference was significant. suggesting that the RH ADV for faces may be generalized to other visuospatial stimuli
($F(1,21)=3.75$, $p<.07$)

- * There was no evidence of any relationship between speed and accuracy on inverted face recognition. The positive association observed for LH speed and accuracy in Study 1 was significantly different from the equivalent correlation in Study 4.
($z=2.06$, $p<.05$)

- * There was no evidence for a highly efficient LH ADV group similar to the one that existed for the processing of upright faces without speech.

- * When complexity of the task is maintained, no evidence of greater detriment to RH than to LH with face inversion.

STUDY 5

INTRODUCTION

The purpose of this study was to observe any differences in performance and in hemispheric lateralization that might occur between the presentation of inverted faces alone and inverted faces with speech. General comparisons between this set of studies and those of upright faces were made. Of particular interest was whether the lack of performance differences between Studies 1 and 2 was related to the ecological relevance of the face speech combination.

METHOD

SUBJECTS

The subjects were recruited and screened exactly as they were for Study 4. They were 22 right handed males and females (1 male and 21 females) with self reported normal hearing and with a mean age of 21.3 (SD=4.9) years. The

data from 7 additional subjects were dropped. Reasons for this included the following: anticipatory keying responses - 3; misunderstood directions - 1; chance performance on the faces - 2; chance performance on speech recognition - 1.

PROCEDURE

The procedure was identical to Study 2, Face recognition with related speech, except just as in Study 4, the faces were inverted, the exposure duration was increased by 110 msec from 65 msec to 175 msec and targets and choices were identical views of the same individual rather than different views.

STUDY 5
INVERTED FACE RECOGNITION RESULTS
ACCURACY AND REACTION TIMES IN LVF AND RVF ON FACE
RECOGNITION

ACCURACY

Accuracy results are reported in Table 16 where they are summarized for all five studies. Subjects correctly recognized a mean of 66.1 (SD=17.0) inverted faces correctly for an overall correctness level of 45.9%. There is only a difference of .2 faces in the number of faces correctly recognized between this study and the corresponding study of upright faces with speech. Performance on inverted faces was calibrated to be equal to performance on silent upright faces. Thus, these results indicate that inverted faces and speech can be processed simultaneously as well as upright faces and speech can.

Subjects recognized a mean of 32.2 (SD=9.1) inverted faces correctly in the LVF and a mean of 33.9 (SD=9.1) inverted faces in the RVF. As in all previous studies, there is no evidence of a difference between the visual fields in the number of faces correctly recognized ($F(1,21)=2.00$, $p=.18$).

There was a significant block effect ($F(5,105)=6.48$, $p<.001$) and a significant linear trend ($t=4.01$, $p<.001$)

reflecting the fact that the percent of inverted faces correctly recognized increased from 37.1% in Block 1 to 53.8% in Block 6. (Block data are in Appendix A, Table A14.)

REACTION TIME/SPEED

A reciprocal square root transformation was applied to the reaction time data to correct for lack of homogeneity of the variances. Raw data are presented in Table 17 and summarized for all five studies. (Analysis based upon non-transformed measures is in Appendix A, Table A1.)

The total mean correct reaction time was 5418 msec (SD=2117) with a mean correct reaction time of 5356 msec (SD=2075) in the LVF and a mean correct reaction time of 5481 msec (SD=2207) in the RVF. The 125 msec difference between the visual fields was not significant based upon a repeated measures ANOVA ($F(1,21)=.66$, $p=.43$). There was a significant block effect ($F(5,105)=3.00$, $p<.02$) and a significant linear trend ($t=-2.91$ $p<.01$) reflecting that reaction times decreased across blocks. (Block data are in Appendix A, Table A15.)

The mean correct reaction time for inverted faces in the presence of speech was 793 msec slower than the mean

correct reaction time for silent inverted face processing, as can be seen in Table 17. However, when the data from the two studies were analyzed together, using a 2 by 2 repeated measures ANOVA, this difference was not significant ($F(1,42)=1.17$, $p=.30$).

The difference between correct and incorrect responses was significant ($F(1,21)=4.96$; $p<.04$) with correct responses being faster. When incorrect responses in the LVF and RVF were analyzed, the difference was not significant ($F(1,23)=3.43$, $p<.09$) with the LVF responses 207 msec faster than the RVF responses. See Appendix A, Table A16. When incorrect reaction times were analyzed across time, there was no evidence of a block effect ($F(5,105)=.46$, $p=.82$). This is the only study for which the incorrect responses did not get faster over time, along with the correct ones.

TABLE 16
STUDY 1 - STUDY 5 COMPARED
ACCURACY IN LVF AND RVF ON FACE RECOGNITION
NUMBER OF FACES CORRECTLY RECOGNIZED

<u>STUDY</u>	<u>N</u>	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
STUDY 1	25	34.4	(9.7)	34.6	(11.5)	69.0	(19)
STUDY 2	25	33.0	(6.6)	32.9	(6.8)	65.9	(12)
STUDY 3	25	32.6	(8.4)	31.4	(7.8)	64.0	(14)
STUDY 4	22	34.6	(7.9)	35.3	(7.0)	69.9	(14)
STUDY 5	22	32.2	(9.1)	33.9	(9.1)	66.1	(17)

TABLE 17
STUDY 1 - STUDY 5 COMPARED
FACE RECOGNITION REACTION TIME IN LVF AND RVF
REACTION TIMES FOR CORRECT RESPONSES
(IN MSEC)

<u>STUDY</u>	<u>N</u>	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
STUDY 1	25	4213	(1260)	4579	(1458)	4396	(1294)
STUDY 2	25	4666	(1285)	4791	(1663)	4729	(1401)
STUDY 3	25	4357	(913)	4375	(1329)	4366	(1067)
STUDY 4	22	4557	(1168)	4693	(959)	4625	(1042)
STUDY 5	22	5356	(2075)	5481	(2207)	5418	(2117)

STUDY 5
RESULTS
RELATIONSHIP BETWEEN SPEED AND ACCURACY ON INVERTED FACE
RECOGNITION

Correlations between reaction time and number correct on faces were calculated and are reported in Table 18 along with a summary for all five studies. As was the case in the study of inverted faces without speech (Study 4), there was no evidence of a relationship between speed and accuracy. This is contrary to what was observed in the parallel study, the study of upright faces and related speech (Study 2), where speed in the RVF (LH) was positively correlated with accuracy in the LVF (RH).

To explore individual differences, subjects were divided based upon relative processing speed. As a result of this post hoc division of subjects, there were 13 subjects who were faster in their responses to faces in the LVF and 9 who were faster in their responses to faces in the RVF. This breakdown of subjects did not differ significantly from what would have been expected by chance (Binomial Test, $p=.53$)

The two groups recognized almost the same number of faces correctly. Although the LVF ADV group was 720 msec faster than the RVF ADV group, this difference was not significant ($F(1,20)=.46$, $p=.51$). A summary of the data

based upon processing speed advantage groups is provided in Tables 19 and 20.

TABLE 18
STUDY 1 - STUDY 5 COMPARED

PEARSON CORRELATIONS BETWEEN SPEED AND ACCURACY ON FACE
RECOGNITION

	TOTAL CORRECT LVF	TOTAL CORRECT RVF	TOTAL CORRECT
<u>STUDY 1</u>			
LVF CORRECT RT	$r(25) = .02$	$r(25) = -.25$	$r(25) = -.14$
RVF CORRECT RT	$r(25) = -.25$	$r(25) = -.52^{**}$	$r(25) = -.43^{*}$
TOTAL CORRECT RT	-	-	$r(25) = -.31$
<u>STUDY 2</u>			
LVF CORRECT RT	$r(25) = -.32$	$r(25) = -.12$	$r(25) = -.24$
RVF CORRECT RT	$r(25) = -.41^{*}$	$r(25) = -.06$	$r(25) = -.25$
TOTAL CORRECT RT	-	-	$r(25) = -.26$
<u>STUDY 3</u>			
LVF CORRECT RT	$r(25) = -.23$	$r(25) = .10$	$r(25) = -.08$
RVF CORRECT RT	$r(25) = -.12$	$r(25) = .13$	$r(25) = .00$
TOTAL CORRECT RT	-	-	$r(25) = -.03$
<u>STUDY 4</u>			
LVF CORRECT RT	$r(22) = -.01$	$r(22) = .09$	$r(22) = .04$
RVF CORRECT RT	$r(22) = -.09$	$r(22) = .07$	$r(22) = -.01$
TOTAL CORRECT RT	-	-	$r(22) = .01$
<u>STUDY 5</u>			
LVF CORRECT RT	$r(22) = -.11$	$r(22) = -.05$	$r(22) = -.08$
RVF CORRECT RT	$r(22) = -.12$	$r(22) = -.07$	$r(22) = -.08$
TOTAL CORRECT RT	-	-	$r(22) = -.09$

* $p < .05$

** $p < .01$

TABLE 19
STUDY 1 - STUDY 5 COMPARED

INDIVIDUALS GROUPED BY PROCESSING SPEED ADVANTAGE
FASTER IN LVF (LVF ADV) VERSUS FASTER IN RVF (RVF ADV)

ACCURACY IN LVF AND RVF ON FACE RECOGNITION
NUMBER OF FACES CORRECTLY RECOGNIZED

	<u>N</u>	<u>LVF</u> MEAN SD	<u>RVF</u> MEAN SD	<u>TOTAL</u> MEAN SD
<u>STUDY 1</u>				
LVF ADV	19	33.1 (9.0)	31.7 (8.7)	64.8 (16.6)
RVF ADV	6	38.3 (11.6)	44.0 (15.0)	82.3 (23.2)
<u>STUDY 2</u>				
LVF ADV	13	32.7 (8.1)	34.2 (6.6)	66.9 (13.7)
RVF ADV	12	33.3 (5.0)	31.5 (7.1)	64.8 (11.6)
<u>STUDY 3</u>				
LVF ADV	10	35.4 (11.2)	32.7 (11.0)	68.1 (20.1)
RVF ADV	15	30.8 (5.6)	30.5 (5.1)	61.3 (8.0)
<u>STUDY 4</u>				
LVF ADV	15	32.9 (6.3)	34.1 (5.5)	67.0 (11.1)
RVF ADV	7	38.1 (10.3)	38.0 (9.4)	76.1 (18.5)
<u>STUDY 5</u>				
LVF ADV	13	32.4 (10.5)	33.8 (10.9)	66.2 (20.6)
RVF ADV	9	32.0 (7.4)	34.0 (6.4)	66.0 (12.6)

TABLE 20
STUDY 1 - STUDY 5 COMPARED

INDIVIDUALS GROUPED BY PROCESSING SPEED ADVANTAGE
FASTER IN LVF (LVF ADV) VERSUS FASTER IN RVF (RVF ADV)

FACE RECOGNITION REACTION TIME IN LVF AND RVF
REACTION TIMES FOR CORRECT RESPONSES
(IN MSEC)

	N	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
<u>STUDY 1</u>							
LVF ADV	19	4129	(1182)	4731	(1399)	4430	(1225)
RVF ADV	6	4476	(1575)	4096	(1670)	4286	(1618)
<u>STUDY 2</u>							
LVF ADV	13	4589	(1338)	5243	(1997)	4916	(1608)
RVF ADV	12	4749	(1278)	4302	(1088)	4525	(1172)
<u>STUDY 3</u>							
LVF ADV	10	4427	(1109)	5096	(1691)	4761	(1361)
RVF ADV	15	4310	(796)	3894	(756)	4102	(759)
<u>STUDY 4</u>							
LVF ADV	15	4262	(947)	4652	(846)	4457	(886)
RVF ADV	7	5190	(1413)	4781	(1238)	4985	(1322)
<u>STUDY 5</u>							
LVF ADV	13	5449	(2306)	5976	(2520)	5713	(2408)
RVF ADV	9	5221	(1813)	4766	(1512)	4993	(1650)

HOW WELL DO PARTICIPANTS DO TWO THINGS AT ONCE?
STUDY 5 - INVERTED FACE RECOGNITION AND RELATED SPEECH

AUDITORY RECOGNITION SESSION

The purpose and procedure for the auditory recognition session was identical to Study 2. Speech was related to inverted faces.

RESULTS

ACCURACY AND SPEED ON DELAYED SPEECH RECOGNITION

Performance is summarized in Table 21 along with a summary of the data from all three studies. Subjects correctly recognized 84.1% of the speech stimuli, which is better than the 50% chance level. Arcsine transformations were applied to the percentages prior to performing ANOVAs with four repeated measures. As in the other two studies which involved speech (Study 2 and Study 3), there was a significant main effect of word type based upon percent correct ($F(3,63)=17.28$, $p<.01$) and based upon reaction times ($F(3,63)=3.86$, $p<.02$).

TABLE 21
STUDY 2, STUDY 3 and STUDY 5 COMPARED
PERFORMANCE ON DELAYED SPEECH RECOGNITION

PERCENT CORRECT BY WORD TYPE

<u>STUDY</u>	<u>N</u>	<u>OLD VOICE</u> <u>NEW WORD</u>	<u>OLD VOICE</u> <u>OLD WORD</u>	<u>NEW VOICE</u> <u>NEW WORD</u>	<u>NEW VOICE</u> <u>OLD WORD</u>	<u>** TOTAL</u> <u>%CORRECT</u>
		MEAN (SD)	MEAN (SD)	MEAN (SD)	MEAN (SD)	MEAN (SD)
2	25	90.5 (12.1)	74.2 (12.0)	96.5 (10.5)	84.0 (20.6)	82.2 (7.0)
3	25	92.0 (10.8)	76.2 (13.5)	99.5 (2.5)	87.5 (18.0)	84.6 (6.6)
5	22	93.8 (10.0)	76.5 (13.4)	97.7 (6.3)	83.5 (22.0)	84.1 (8.4)

CORRECT REACTION TIME BY WORD TYPE
(IN MSEC)

<u>STUDY</u>	<u>N</u>	<u>OLD VOICE</u> <u>NEW WORD</u>	<u>OLD VOICE</u> <u>OLD WORD</u>	<u>NEW VOICE</u> <u>NEW WORD</u>	<u>NEW VOICE</u> <u>OLD WORD</u>	<u>TOTAL</u>
		MEAN (SD)	MEAN (SD)	MEAN (SD)	MEAN (SD)	MEAN (SD)
2	25	3065 (1134)	3322 (998)	3024 (919)	4022 (2613)	3358 (1210)
3	25	2983 (883)	3382 (765)	2577 (677)	3398 (1374)	3085 (755)
5	22	3004 (1091)	3478 (1045)	3045 (813)	4150 (2403)	3419 (985)

** The category of OLD VOICE OLD WORD had 24 target; whereas the other categories each had only 8 targets. Thus the total % correct is not the mean of each of the category percentages

STUDY 5
RESULTS
RELATIONSHIP BETWEEN INVERTED FACE RECOGNITION AND DELAYED
SPEECH RECOGNITION

Performance on speech recognition was better than chance; so that, the relationship between accuracy on inverted face recognition and accuracy on delayed speech recognition was examined. Correlations were calculated between mean number correct in the left and in the right visual fields and total correct for the entire auditory session and for the largest single word type - old voice/old word. These correlations were generally positive, but only the relationships between the number of inverted faces correct in the RVF (LH) and speech performance on old voice/old word ($r(22)=+.41$, $p<.06$) and total faces correct and speech performance on old voice/old word ($r(22)=+.39$, $p<.08$) approached significance. They are summarized in Table 22 along with the data from the other three speech studies.

In Study 2, those subjects who responded more quickly to upright faces presented to the RVF went on to do better on speech recognition. In the current study there is no evidence that the RVF ADV group did any better on speech recognition, as indicated by an ANOVA with two between group factors on speed advantage and four within group factors on

word type ($F(1,20)=.01$, $p=.92$). The non-significant trend is opposite what was observed in Study 2, with those individuals who have a RVF ADV on inverted faces doing worse on speech recognition than those with a LVF ADV. Table 23 contains a summary of this data from all three speech studies.

TABLE 22
STUDY 2, STUDY 3 AND STUDY 5 COMPARED

PEARSON CORRELATIONS BETWEEN FACE AND SPEECH RECOGNITION
ACCURACY

SPEECH PERFORMANCE

	TOTAL AUDITORY	OLD VOICE OLD WORD
<u>STUDY 2</u>		
LVF	$r(25) = .36!$	$r(25) = .44 *$
RVF	$r(25) = .45*$	$r(25) = .55**$
TOTAL	$r(25) = .44*$	$r(25) = .54**$
<u>STUDY 3</u>		
LVF	$r(25) = -.12$	$r(25) = -.13$
RVF	$r(25) = .37!$	$r(25) = .30$
TOTAL	$r(25) = .14$	$r(25) = .09$
<u>STUDY 5</u>		
LVF	$r(22) = .24$	$r(22) = .33$
RVF	$r(22) = .31$	$r(22) = .41$
TOTAL	$r(22) = .29$	$r(22) = .39$

! $p < .10$
* $p < .05$
** $p < .01$

TABLE 23
STUDY 2, STUDY 3 AND STUDY 5 COMPARED

INDIVIDUALS GROUPED BY PROCESSING SPEED ADVANTAGE
FASTER IN LVF (LVF ADV) VERSUS FASTER IN RVF (RVF ADV)

PERCENT CORRECT BY WORD TYPE ON DELAYED SPEECH RECOGNITION
(IN MSEC)

<u>STUDY N</u>	<u>OLD VOICE NEW WORD</u>	<u>OLD VOICE OLD WORD</u>	<u>NEW VOICE NEW WORD</u>	<u>NEW VOICE OLD WORD</u>	<u>**TOTAL</u>
	MEAN (SD)	MEAN (SD)	MEAN (SD)	MEAN (SD)	MEAN (SD)
<u>STUDY 2</u>					
LVF 13	84.6	74.4	93.3	79.8	80.1
ADV	(13.6)	(10.9)	(14.1)	(23.7)	(6.8)
RVF 12	96.9	74.0	100.0	82.0	84.5
ADV	(5.7)	(13.7)	(000)	(16.4)	(6.6)
<u>STUDY 3</u>					
LVF 10	91.3	74.6	100.0	82.5	82.9
ADV	(8.4)	(16.0)	(000)	(25.1)	(7.3)
RVF 15	92.5	77.2	99.2	90.8	85.7
ADV	(12.3)	(12.0)	(3.2)	(11.0)	(6.1)
<u>STUDY 5</u>					
LVF 13	92.3	79.5	97.1	84.6	85.4
ADV	(12.0)	(14.4)	(7.5)	(17.8)	(8.2)
RVF 9	95.8	72.2	98.6	81.9	82.2
ADV	(6.3)	(11.2)	(4.2)	(28.0)	(8.8)

** The category of OLD VOICE OLD WORD had 24 target; whereas the other categories each had only 8 targets. Thus the total % correct is not the mean of each of the category percentages

STUDY 5
SUMMARY OF OBSERVATIONS

- * Subjects are still able to do two things at once even though the faces are inverted. The inverted face/speech combination seems to be "as special" as the upright face/speech combination.
- * Performance on the auditory session is well above chance (84.1%) with a significant main effect of word type based upon percent correct and reaction time. Performance on category of new voice/new word is 97.7%.
(Percent Correct: $F(3,63)=17.28$, $p<.01$)
(Reaction Time: $F(3,63)=3.86$, $p<.02$)
- * A positive correlation between inverted face and speech performance on old voice/old word for only the LH approaches significance
($r(22)=+.41$, $p<.06$).
This contrasts with Study 2 where both the LH and the RH exhibited significant positive correlations.
- * No relationship between speed and accuracy on inverted face performance, contrary to processing of upright faces and related speech where there was a positive correlation between LH speed and RH accuracy.
- * RH responses to faces no longer approach being significantly different from LH responses, as they had been for processing silent inverted faces.

STUDY 5
FACE RECOGNITION WITH RELATED SPEECH
DISCUSSION

Is the speech face combination special? No. At least in terms of overall performance it appears to be no more or less special than the speech inverted face combination. This seems to be the answer to the main question being asked in the execution of Studies 4 and 5. There was no evidence of a difference in either accuracy or speed on face or speech recognition performance between processing silent inverted faces and processing inverted faces simultaneously with speech, just as there had been no evidence of alterations in performance between upright face processing alone and with speech. To the extent that an inverted face captures "other than face" processing, it does not seem to be the case that the ecological significance or special nature of the speech face combination was responsible for the resistance to performance decrements observed in the study of upright faces.

At the same time, there is no indication of any lateralized effect due to inversion when broadly comparing Study 4 to Study 1. As mentioned in the introduction to Studies 4 and 5, there is evidence that the RH is more adversely affected by inversion than the left. When the

complexity of the stimuli was altered to produce similar error rates between Study 1 and Study 4, the goal of a 50% error rate was achieved by assessing total number of faces correctly recognized. It was not calibrated separately as a 50% error rate in each visual field. Thus, one might have expected that in Study 4, the RH would have been more adversely affected by inversion than the left. The expectation might have been that fewer faces would have been recognized in the RH and, even more likely, that RH responses to faces would have been slower than LH ones. This was not the case. Not only was there no evidence for lateralized differences in accuracy on faces favoring the LH, but responses to faces are still faster in the RH than in the LH. This difference in speed of response approaches significance. It is far beyond the scope of this dissertation to explore the voluminous face inversion lateralization literature; however, the results observed here raise a question with relation to it. On the one hand, these results might simply be viewed as a failure to replicate the lateralized effects of inversion. On the other hand, in the current study, inversion was most probably handled differently from the way it was handled in the majority of inversion studies, because in this study task difficulty in the inverted and upright conditions was equalized. The manipulations that were made in this

experiment to adjust task complexity, i.e. increases in exposure duration and matching same pictures as opposed to matching different views of the same individual have been found to favor the LH over the RH (Sergent, 1983). Based upon Sergent's work, it seems that these manipulations should have made it even more likely that the RH would be adversely affected to a greater degree while performing the inverted task. Considering this, one might ask if the effect described in the literature is at least somewhat related to a confound between task complexity and inversion. It would be interesting to explore this issue further by comparing lateralized performance in the following four conditions:

1. processing upright lateralized faces
2. processing inverted lateralized faces
3. processing inverted lateralized faces manipulated so that they are equally as difficult as the upright ones
4. processing lateralized upright faces that have been manipulated in the same way as the faces in condition 3.

The results of such a study would have a bearing on some of the assumptions involved with regard to using inverted faces as non-face stimuli in the current studies.

The fact that in Study 4 a tendency for response times to favor the RH over the LH was observed deserves further

discussion. While the effect is weak, this observation raises a question in addition to the already described one concerning the lack of RH decline during inversion. Is the RH processing speed advantage, and indeed, other patterns observed in Study 1, unique to faces? The answer is that the observed RH advantage may not be. Of course, even asking this question takes one back to Yin in 1969 and to one of the central debates in the face perception literature - one related to whether face processing is unique or special (e.g. Ellis & Young, 1989, Levine, 1989, Morton & Johnson, 1989). Although not designed to address this question, it is impossible to ignore the similarity in the data related to the RH processing speed advantages in Study 1 and Study 4. Furthermore, for processing inverted faces with speech, there is not even weak evidence for a difference in processing speed.

Despite this similarity, there are other differences between the upright and inverted face situations that may point to certain unique characteristics in the processing of upright faces. Before describing those, it must again be remembered that the manipulations made in order to equalize the difficulty of the inverted and upright task allow for two possibilities for any observed differences between these conditions. The first possibility may pertain to whatever is unique to processing silent faces and faces with speech.

The second is related to the manipulations made, i.e. the increase in exposure duration and matching same pictures as opposed to matching different views of the same individual. Thus the following discussion of differences only presents possibilities.

One difference between processing silent upright faces and silent inverted ones is that the positive relationship between speed and accuracy within the LH seems to emerge only for upright faces. In fact, the correlations between speed and accuracy within the LH are significantly different between the upright face (Study 1) and the inverted face (Study 4) studies. For upright faces, a complementary process between speed and accuracy in the LH is suggested, but for inverted faces there is no relationship between the two. Furthermore, there is no other relationship between speed and accuracy within or between the hemispheres for processing of inverted faces. As suggested earlier, this lack of relationship may be a reflection of the lack of a highly routinized or practiced approach to this atypical processing situation.

Related to this observation, is a general comparison of the LH ADV groups in Studies 1 and 4. In Study 4 a highly proficient LH ADV group did not emerge. In Study 1, it will be remembered that this small group was significantly better at recognizing faces overall, demonstrated a non-significant

trend to respond to faces faster when compared to the RH ADV subjects and exhibited a trend towards better recognition of faces in the the LH as compared to the RH. For inverted faces, there are no significant differences related to such subjects (although, similar to Study 1, there is a non-significant trend for it to do better on faces overall). Contrary to Study 1, performance in the right and left hemispheres for the LH ADV group is virtually identical. The existence of the relationship between LH speed and accuracy, as well as the characteristics of the LH ADV group are indicative of how the processing invoked in the presence of upright faces might be different from that for inverted faces. (For a discussion of the possible implications of this LH processing style, refer to the discussion of Study 2.)

Similar to the lack of correlation between left hemisphere speed and accuracy that exists for processing silent upright faces but not for silent inverted faces, is the comparison between the speed/accuracy relationship in upright face and speech processing (Study 2) and the speed/accuracy relationship in inverted face and speech processing (Study 5). In Study 2, speed in the LH is positively correlated with accuracy in the RH for face processing and generally, with upright faces there is a breakdown of subjects indicating a greater number with

hemispheric advantage based upon speed and accuracy reversed. Additionally, the group that is relatively faster in the LH than in the RH goes on to do significantly better on speech processing. It was suggested in the discussion of Study 2 that perhaps this reversed advantage, particularly the case of being faster in the LH and more accurate in the RH might reflect an optimum processing style, allowing maintenance of face performance at a high level, but with superior speech processing performance. In the presence of inverted faces, there are no indications of such processing. There are no relationships between speed and accuracy on face performance and no evidence of the LH ADV group on faces performing better on speech. Thus, these observations in relation to concurrent face and speech processing also suggest a processing mode that is specialized for the processing of upright faces with speech.

FINAL SUMMARY OF OBSERVATIONS

HEMISPHERIC ADVANTAGE ON FACE RECOGNITION

- * A RH reaction time ADV for processing upright silent faces proved very fragile, and was not in evidence, with the concurrent encoding and processing of speech regardless of whether the speech was related or unrelated to the faces. (See Table 17)
- * Similarly, a distribution of subjects where the majority had a RH ADV based upon processing speed was only significantly different from chance for the processing of upright silent faces. (See Table 19)
- * Processing upright silent faces elicited a highly proficient LH ADV processing style among some subjects which did not emerge when processing upright faces with speech or when processing inverted faces. (See Table 19)
- * Those who responded more quickly to upright faces and related speech in the LH (LH ADV), went on to perform better on speech recognition. There was no indication of this being the case for the corresponding group of subjects when faces were inverted and only a non-significant trend in this direction when the speech was unrelated. (See Table 23.)
- * Two measures of hemispheric advantage - one based upon reaction time and the other based upon accuracy - were used. This is not typically done. These measures did not always correspond, suggesting that hemispheric advantage inferred from different measures may not necessarily reflect the same underlying processes and should not be equated as is often done in the literature.

FINAL SUMMARY OF OBSERVATIONS (cont.)

FACE AND SPEECH RECOGNITION PERFORMANCE

- * Face recognition performance, based upon accuracy and speed, was highly resistant to the increased processing load created by the presentation of both related and unrelated incidental speech. The ecological importance of the speech face combination does not seem to explain this since performance was also maintained for the processing of inverted faces with and without speech. (See Tables 16 & 17)

- * Subjects were able to do two things at once despite the face that the speech was incidental. Besides showing no performance decrement on face recognition in all instances where speech was presented - related, unrelated, and with inverted faces - subjects were also able to perform remarkably well on surprise speech identification. (See Table 21.)

- * Observations related to performance in each speech category (e.g. old voice/new word) point toward word having been more salient than voice even though there were 36 repetitions of a particular voice and only 6 repetitions of a particular word. (See Table 21.)

FINAL SUMMARY OF OBSERVATIONS (cont.)

ASSOCIATION OF FACE AND SPEECH

- * There was no indication of multimodal facilitation of face performance due to the relationship between face and speech, but there may have been other subtle effects of the association.
- * Only in the processing of upright faces and related speech were there significant positive correlations between face recognition in both the LH and the RH and speech recognition, and between total face recognition and speech recognition. (See Table 22.)
- * When upright faces and speech were unrelated there were some suggestions of a trade-off in performance between speech and face processing, but only for the RH.
- * Females, more frequently than males, recognized the fact that there was a relationship between a face and a voice.

FINAL SUMMARY OF OBSERVATIONS (cont.)

FACE INVERSION

- * Contrary to the literature, the RH was not more affected by face inversion than the left. Rather, the trend toward a RH ADV was still evident and approached significance. Since faces were inverted after manipulations to control task difficulty, it seems possible that in past studies the effects of inversion and of task complexity may have been, to some degree, confounded.
- * Patterns of processing silent inverted faces, including non-significant trends toward a RH reaction time ADV and a distribution of subjects where more had a RH ADV than a LH ADV, were similar enough to those for silent upright faces to question whether the upright face observations are unique to faces. (See Tables 17 & 19)
- * Significant correlations between speed and accuracy on face recognition only emerged in what might be considered ecologically typical scenarios, viz. processing upright silent faces and processing upright faces with related speech. (For silent upright faces, speed and accuracy within the LH were positively correlated and for upright faces with speech, speed in the LH was positively correlated with accuracy in the RH.) (See Table 18.)

CHAPTER 6

GENERAL DISCUSSION

INTRODUCTION

This dissertation was undertaken as a result of being intrigued with the talking face as an ecologically relevant multimodal stimulus for which a critical role has been proposed in the normal development of hemispheric specialization (Turkewitz, 1990). In moving to the actual execution of these studies, an attempt was made to come as close to a naturalistic situation as feasible. Unfortunately, presentation of talking faces was not feasible. Rather, two separate stimuli were presented simultaneously, a still face and a spoken word. Until now, the concurrent processing of these bimodal stimuli had never been studied within the context of hemispheric lateralization. Since there was no precedent in the literature upon which to formulate meaningful hypotheses, none were proposed at the outset of this work. The studies were intended to be primarily descriptive.

However, some general questions were asked and some general answers to these questions were found. Beyond this, many specific observations were made. The key ones are summarized in "Final Summary of Observations" on pp. 187-190.

As befits a descriptive study, many new questions were also generated. These are summarized in Appendix C "Summary of New Questions". In the course of this dissertation, fairly extensive and specific discussions have been included after each study. Therefore, the remaining discussion will not repeat that level of detail. Instead, it will touch on a few general issues, make a digression or two, highlight some of the questions that have arisen and discuss some possible approaches to answering them.

HEMISPHERIC ADVANTAGE AND FACE RECOGNITION

Among the questions that were asked prior to performing these studies were the following: "When face processing and speech processing proceed concurrently, do the underlying cognitive functions exhibit the same lateral advantage as when they occur in isolation? Or does simultaneous processing in two modalities result in differing strategies of processing with concomitant alterations in hemispheric advantage?" The first part of this question was answered in the negative as explained in the discussion of Study 2: "It seems that concurrent processing of speech with faces might simultaneously interfere with the emergence of an overall RH ADV, in terms of speed of response to faces, and also of a highly superior LH processing style, one that might, as discussed previously, be more reliant on featural processing. Thus, speech processing may upset lateralized face processing, and in paradoxical ways, possibly playing a role in the non-emergence of an overall RH ADV as well as a specialized LH ADV exhibited by a subset of individuals."

The answer to the second part of this question is more complex. No overall advantage emerged during the concurrent processing of face and speech; the advantage did not simply shift from a RH to a LH ADV, for instance. Thus, there was no direct evidence of a change in processing strategy. But

observations based upon dividing subjects into processing speed advantage groups suggest that alterations in processing strategies may have occurred. The specific observations suggesting this include the disappearance of the highly proficient LH ADV group that had existed when processing upright silent faces and alterations in the distribution of subjects into RH ADV and LH ADV groups between these two situations. One overarching question that could be considered in relation to this is whether the alterations in laterality brought about in the presence of concurrent speech are simply by-products of what must occur to process the speech or whether these changes in hemispheric advantage are reflective of alterations which actually facilitate the ability to co-process faces, or inverted faces, and speech.

In the discussion of Study 2, the observations just described were explored in terms of priming and interference. An issue was raised there, concerning measures of lateralization based upon reaction time and accuracy, which will be elaborated upon now.

REACTION TIME AND ACCURACY - APPLES AND ORANGES?

Throughout the lateralization literature, two measures of hemispheric advantage have typically been used. One is based upon reaction time and the other is based upon the

number correct or accuracy. Few studies deal, as these have, in both measures simultaneously. Once an advantage has been observed based upon either measure, the advantage is usually discussed as though it exists apart from the measure from which it was inferred. There seems to be a common assumption that both measures reflect the same underlying processes. The results from the current studies raise serious questions about using reaction time and accuracy advantages synonymously. The fact that a RH reaction time ADV for upright silent faces was not accompanied by a RH ADV based upon accuracy was the first observation that challenged this approach. Questions were more strenuously raised in finding that, for processing upright faces with related speech, the majority of individuals exhibited a reversed advantage, i.e. they were more accurate in one hemisphere, but faster in their responses to faces in the other. These disassociations between advantages based upon reaction time and accuracy indicate that comparing hemispheric advantages inferred from these different sources may well be like "comparing apples and oranges".

When both measures of advantage coincide, it may mean that one hemisphere is more efficient, more activated, more attentive and more accurate than the other. In the case where there is a particular advantage based upon one

measure, but not the other, or where there are reversed advantages, the interpretation is far more complex. As partially raised in the discussion of Study 2, some of the possible interpretations of differing reaction times between the hemispheres (or for the same hemisphere under different conditions) include the following:

1. a difference in efficiency
2. priming - activity related to one process in a particular hemisphere which results in faster responses in other processes
3. differences in attention (attention activation type explanation)
 - * faster RT's as the result of more attention directed toward the visual field opposite the hemisphere that is most activated
 - * slower RT's due to less attention - as might occur in guessing
4. interference or increased processing load resulting in slower RT's
5. interhemispheric transmission time (only for differences between the hemispheres)
6. RT's produced as a net effect of any combination of these processes

Thus, the interpretation of a difference in a reaction time is problematic in its own right. Coupled with differing advantage based upon accuracy, it becomes very difficult. However, differentiation between the two measures of advantage helps somewhat. As was discussed in relation to Study 2, if reaction time advantage and accuracy advantage are manifestations of potentially separate underlying activity, then they and their underlying activity can be separately affected by whatever else is occurring.

For instance, for Study 2 it was suggested that speech processing produced priming which was involved in the disappearance of a RH reaction time advantage. It was suggested that speech processing simultaneously prevented the emergence of a group of individuals with a LH ADV that coupled LH accuracy and speed, and involved more accurate face recognition overall. Some of the most interesting questions spurred by these studies are based upon trying to interpret these reaction time advantages and are summarized in Appendix C "Summary of New Questions: Hemispheric Advantage and Face Recognition".

FACE AND SPEECH RECOGNITION PERFORMANCE

THE RACE BETWEEN FACE AND INCIDENTAL SPEECH - NEITHER LOSES

At the outset of these studies there was no way of knowing what might be expected in relation to hemispheric advantage, but it was thought, if not hypothesized, that concurrent processing of faces and incidental, and especially unrelated speech, would lead to decreased performance on face processing and/or poor performance on speech recognition. This expectation was based upon a number of factors. First, the task was not appraised as being the type of simple or boring task where heteromodal stimulation improves performance (Stanislaw, 1988). The task was quite complex. Second, in the case where the speech was unrelated, it was felt that there was no possibility for multimodal facilitation. (For related speech, the possibility of improved performance was considered.) Third, in concurrent processing situations it is more common to observe some decrease in performance than to observe undiminished performance. And lastly, these studies involved explicit memory of incidentally presented speech which often proves quite difficult.

Despite these factors, neither face recognition accuracy nor speed of response was adversely affected by the

concurrent processing of speech, even in the situation where the speech was unrelated to the faces. Expectations were not fulfilled. Although speech recognition was not tested alone, (as it would have been were this dissertation primarily dealing with divided attention issues) explicit memory for incidental speech was also very good. Within the context of this dissertation an answer was proposed for these unexpected observations. It was suggested that the ecological importance and special nature of the face speech combination - the "talking face" that inspired these studies - was responsible for the lack of decline in face performance and the surprisingly good memory for incidentally presented speech. The following specific question was formulated: was the special nature of the speech face combination producing the capability for parallel processing of the two with no loss in performance and despite the fact that the speech was incidental? This was tested by studying the proficiency of processing silent inverted faces and inverted faces with incidental speech - the inverted face speech combination. This non-ecological combination turned out to be "special" also. Thus, no evidence was found to substantiate the ecological importance of the face speech combination as being responsible for the observations. The processing of inverted faces - non-faces according to the literature - seemed just as resistant to a

decline in performance in the presence of speech and incidental speech was remembered just as well.

Although a slight digression from the issue of lateralization, per se, some further speculations on these observations will be made. Perhaps it is the speech itself that is special and highly salient. Perhaps speech would be easily processed with any visual stimuli that are presented in a manner similar to the upright and inverted faces. This could be tested by combining a lateralized recognition task of some other complex visual stimuli with speech. The only danger in attempting such a study is that it might spawn a Yin-like search for the appropriate visual stimuli. Landscapes, tables, houses, dogs, inverted dogs ...? Or it could be tested by simultaneously presenting faces and some other incidental auditory stimuli for delayed memory - nonsense syllables or music, for instance.

Another thought is that perhaps it is not speech in general, but something related to the characteristics of the particular faces and the particular speech used in this experiment which might be creating the ability to co-process the two so easily. Despite the ecological interest that guided this work, the faces presented here were far from real life faces. They were presented on a computer screen, were static, were black and white and were presented for a very short duration in an unnatural arrangement. They were

in many ways degraded. (Keep in mind, however, that these faces were more natural, due to the use of different views of the same individual and the high resolution graphics, than many that have been used to gather much of what is scientifically known about face perception.) The speech, on the other hand, was much closer to real life speech. Although lacking any visual component, i.e. seen speech, and although taped and played through headphones, it was presented at a conversational volume and a normal speed not unlike what one might experience when listening on a telephone. It was not particularly degraded. Furthermore, the specific words chosen, although not chosen for these reasons, had been shown to have high imagery and recall (Paivio, 1968). Therefore, it was probably much easier to process the speech than the faces.

Perhaps a balance of processing resources occurred between attention consciously directed to difficult degraded stimuli and incidental learning of salient non-degraded naturalistic stimuli. Such a balance allowed both faces and speech to be attended to simultaneously. This idea could be tested by creating a true divided attention paradigm. This could be done instructionally by telling subjects about the speech and telling them that they must attend to it in order to prepare for a memory test.

Another, altogether different, possibility concerning the ability to concurrently process both speech and upright and inverted faces may be related to the specific timing of the concurrence. The face speech concurrence in these studies existed only at the encoding stage of processing and lasted for 65 msec. Given a mean duration of 700 msec per word, the speech was then typically presented for an additional 635 msec after the face was no longer available as a distal stimulus. There was then an additional 1365 msec before the decision process was begun with the presentation of the choices and with the beginning of clocking the reaction time. There was no external concurrence during the actual decision and output stage. The ability to divide attention has been shown to be very sensitive to timing considerations such as the stimulus onset asynchrony (Schriefers & Meyer, 1990, e.g.). It is very possible that different timing, such as a concurrence which runs into the output decision process, might have shown performance to be more sensitive to the increased processing load and may have expressed itself in differing effects on hemispheric lateralization. Perhaps encoding of a speech stimulus simultaneously with the output stage of a face recognition process would be more disruptive to performance than concurrent encoding of bimodal face/speech stimuli.

ASSOCIATION OF FACE AND SPEECH

WERE TWO CODES BETTER, OR EVEN DIFFERENT, FROM ONE?

Another question asked prior to beginning these studies was: "are there alterations in hemispheric advantage when faces and speech become familiar and related, as normally occurs when one learns to bimodally recognize particular individuals?" There was no evidence of major alterations in hemispheric advantage between the situation where speech was related and where it was unrelated; although, there were differences in the relationship between face and speech recognition performance. Since there were no performance differences between these studies either, there was also no clear evidence that an association between the speech and face was made as normally occurs when one learns to bimodally recognize an individual. Therefore, this question remains largely unanswered.

What was observed was that in the study where upright faces and related speech were presented, where presumably an association between a face and speech might have been made, the correlations between face and speech recognition were different from those in the study where no relationship existed. It was the only study where strong positive correlations existed between RH face performance and speech

recognition, significant or otherwise. Thus it seems that a special role for the RH may be suggested for processing the relationship between upright faces and speech. This impression is furthered by the study of upright faces and unrelated speech. In this case there are a number of observations which suggest a trade off between speech and face performance, but only for the RH. These include negative correlations for face performance in the RH and speech performance (significant for the LH ADV group) and good performance on face recognition in the RH of subjects who performed poorly on speech recognition.

It was perhaps unconsciously assumed when designing these studies that the effect of association would be observed through enhancement of performance in the form of multimodal facilitation. However this did not occur; so that, there is no direct evidence supporting the idea that subjects successfully made associations between speech and faces. Yet, there seem to be differences in the observation concerning the correlations between face and speech performance and the performance of high and low performing subjects on speech recognition between the studies involved. Thus it would be useful to have a study where there could be more assurance concerning whether or not an association had been made. One possibility would be to simply make the relationship so clear that it would unavoidably be made,

e.g. by using very dissimilar voices. Another, perhaps superior, method would be to directly test whether a speech/face association had been made by including a post test of target speech/face combinations and distractor combinations. Subjects could then be divided into those who did and who did not successfully make the association. Patterns of performance and hemispheric laterality could be separately examined for these groups. With a group of subjects for whom the relationship between speech and face had been made, the role of the RH and any possible specialty it has in regard to processing such relationships could be better examined.

RETURNING FULL CIRCLE - CAN ANYTHING BE SAID IN RELATION TO
THE TALKING FACE AND THE DEVELOPMENT OF HEMISPHERIC
LATERALITY?

In the beginning of this project, a hope was expressed that since the current studies had been inspired by a theory proposing a role for the talking face in the development of hemispheric specialization, some new insights or questions related to that process might result. That theory proposes that specialization of the right hemisphere for faces evolves due to the combination of the significance of the talking face in the infant's environment and of a prenatally established left hemisphere specialization for language. A division of processing between the right and left hemispheres is posited. Since the left hemisphere is already specialized for processing speech, when a talking face is encountered the right hemisphere develops a specialty for the face. This theory includes a conceptualization of the infant as having a "split-brain" or, at least, little communication between the hemispheres due to an undeveloped corpus callosum. Thus, the infant may parallel process the visual and auditory aspects of the talking face in separate hemispheres.

Adults, of course, do have fully functioning corpus callosums and clearly have communicating hemispheres. In

these studies, adults displayed an uncanny ability to co-process speech and faces, but not based upon a separation of processing between the hemispheres such as occurs in the infant. There is some degree of advantage for the right hemisphere, but it is fragile in the presence of speech. It seems clear that, in the adult, both hemispheres can become engaged in face processing even when speech is present; although certain levels of interference may be occurring. Face processing abilities seem to be distributed. The suggestion was made in the discussion of Study 2, and has been made elsewhere, that different face processing strategies might be employed in each hemisphere. Moreover, different strategies might be employed within different locations in the same hemisphere. A question that these observations and suggestions raises for the developmental model is, what factors in the developmental scenario are conducive to the later development of the type of distributed face processing that is observed in the adult.

One might consider the role of seen speech in this regard. According to the developmental model, the left hemisphere is specialized for auditory speech processing. Evidence exists for some level of intermodal perception of speech beginning as early as 5 months old (e.g., Kuhl & Meltzoff, 1984 and Mackain, et al., 1983). This is still much before completion of the development of the corpus

callosum. Perhaps since the left hemisphere is specialized for auditory speech it also becomes involved in "seeing voices". This would necessarily involve proficiency in featural processing of the mouth. Perhaps when encountering a silent face, this processing is enlisted into a featural form of face processing, one that initially is most concentrated on the mouth. This is one suggestion in relation to the question of what developmental processes are involved in distributing face processing proficiency between the hemispheres.

Aside from this highly speculative question, many new, much more specific questions have been raised based upon the observations made in the course of these studies. As descriptive studies, one of the main goals was to spur such new inquiries. That goal has been fulfilled.

APPENDIX A
ADDITIONAL DATA AND ANALYSES

TABLE A1

LVF RVF DIFFERENCE IN REACTION TIME BASED UPON
NON-TRANSFORMED MEASURES

REACTION TIME IN LVF AND RVF FOR CORRECT RESPONSES

STUDY 1

$F(1, 24) = 4.60, p < .05$

STUDY 2

$F(1, 24) = .40, p = .54$

STUDY 3

$F(1, 24) = .01, p = .92$

STUDY 4

$F(1, 21) = 1.83, p = .20$

STUDY 5

$F(1, 21) = .82, p = .38$

REACTION TIME IN LVF AND RVF FOR INCORRECT RESPONSES

STUDY 1

$F(1, 24) = .72, p = .41$

STUDY 2

$F(1, 24) = .36, p = .56$

STUDY 3

$F(1, 24) = 1.87, p = .19$

STUDY 4

$F(1, 21) = 1.83, p = .20$

STUDY 5

$F(1, 21) = 1.82, p = .38$

APPENDIX A
TABLE A2

STUDY 1
ACCURACY IN LVF AND RVF ON FACE RECOGNITION

NUMBER OF FACES CORRECTLY RECOGNIZED BY BLOCK

	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
BLOCK 1	4.3	(1.5)	4.7	(2.1)	9.0	(2.9)
BLOCK 2	5.7	(2.0)	5.0	(2.3)	10.7	(3.5)
BLOCK 3	5.8	(1.9)	6.0	(2.6)	11.9	(3.7)
BLOCK 4	6.0	(2.5)	6.4	(2.3)	12.4	(4.0)
BLOCK 5	6.1	(2.2)	6.4	(2.2)	12.6	(4.1)
BLOCK 6	6.4	(2.3)	6.1	(3.1)	12.5	(4.8)

APPENDIX A
TABLE A3

STUDY 1
FACE RECOGNITION REACTION TIME IN LVF AND RVF

REACTION TIMES FOR CORRECT RESPONSES BY BLOCK
(IN MSEC)

	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
BLOCK 1	5078	(2001)	6299	(4279)	5688	(2576)
BLOCK 2	4327	(1497)	4534	(1814)	4431	(1513)
BLOCK 3	4180	(1609)	4411	(1882)	4296	(1622)
BLOCK 4	4071	(1383)	3986	(1031)	4028	(1075)
BLOCK 5	3949	(1239)	4176	(1561)	4062	(1208)
BLOCK 6	3671	(1419)	4066	(1723)	3869	(1461)

APPENDIX A
TABLE A4

STUDY 1
FACE RECOGNITION REACTION TIME IN LVF AND RVF

REACTION TIMES FOR INCORRECT RESPONSES
(IN MSEC)

N	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
25	5002	(1538)	5124	(1469)	5063	(1461)

REACTION TIMES FOR INCORRECT RESPONSES BY BLOCK
(IN MSEC)

	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
BLOCK 1	5662	(2078)	5713	(2360)	5687	(2000)
BLOCK 2	4882	(1725)	5211	(1439)	5047	(1426)
BLOCK 3	5274	(2211)	4673	(1690)	4974	(1703)
BLOCK 4	4889	(1564)	4869	(1962)	4879	(1609)
BLOCK 5	4894	(1668)	5272	(1990)	5083	(1638)
BLOCK 6	4411	(1676)	5003	(2051)	4707	(1571)

APPENDIX A
TABLE A5

STUDY 2
ACCURACY IN LVF AND RVF ON FACE RECOGNITION

NUMBER OF FACES CORRECTLY RECOGNIZED BY BLOCK

<u>N</u>	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
BLOCK 1	4.4	(1.6)	4.2	(1.8)	8.5	(2.5)
BLOCK 2	5.2	(1.5)	5.4	(1.8)	10.6	(2.5)
BLOCK 3	5.5	(1.9)	5.1	(1.8)	10.6	(3.0)
BLOCK 4	5.8	(2.1)	6.2	(1.9)	12.0	(3.1)
BLOCK 5	5.9	(2.0)	6.1	(2.1)	12.0	(3.5)
BLOCK 6	6.2	(2.0)	6.0	(1.9)	12.2	(3.3)

APPENDIX A
TABLE A6

STUDY 2
FACE RECOGNITION REACTION TIME IN LVF AND RVF

REACTION TIMES FOR CORRECT RESPONSES BY BLOCK
(IN MSEC)

	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
BLOCK 1	5724	(2692)	5704	(2746)	5714	(2429)
BLOCK 2	4802	(1695)	4963	(1551)	4883	(1493)
BLOCK 3	4776	(1615)	5008	(2610)	4892	(1768)
BLOCK 4	4244	(1356)	4597	(2130)	4421	(1557)
BLOCK 5	4420	(1785)	4198	(1402)	4309	(1434)
BLOCK 6	4028	(1713)	4277	(1591)	4153	(1514)

APPENDIX A
TABLE A7

STUDY 2
FACE RECOGNITION REACTION TIME IN LVF AND RVF

INCORRECT REACTION TIMES
(IN MSEC)

<u>N</u>	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
25	5796	(2126)	5901	(2385)	5848	(2218)

INCORRECT REACTION TIMES BY BLOCK
(IN MSEC)

	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
BLOCK 1	6808	(2870)	6335	(2510)	6571	(2523)
BLOCK 2	5516	(2054)	5603	(2627)	5559	(2189)
BLOCK 3	5624	(2450)	6390	(3471)	6007	(2567)
BLOCK 4	5995	(3088)	5942	(3040)	5969	(2905)
BLOCK 5	5600	(2622)	5994	(2933)	5797	(2403)
BLOCK 6	5236	(2221)	5139	(2364)	5188	(2114)

APPENDIX A
TABLE A8

STUDY 3
ACCURACY IN LVF AND RVF ON FACE RECOGNITION

NUMBER OF FACES CORRECTLY RECOGNIZED BY BLOCK

	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
BLOCK 1	4.0	(1.6)	4.3	(1.9)	8.3	(2.9)
BLOCK 2	5.0	(1.8)	4.2	(2.1)	9.1	(3.3)
BLOCK 3	5.2	(2.3)	4.7	(1.9)	10.0	(3.4)
BLOCK 4	5.3	(2.1)	5.3	(2.0)	10.6	(3.0)
BLOCK 5	6.6	(2.5)	6.2	(2.0)	12.8	(3.8)
BLOCK 6	6.5	(2.4)	6.7	(2.6)	13.2	(4.2)

APPENDIX A
TABLE A9

STUDY 3
FACE RECOGNITION REACTION TIME IN LVF AND RVF

REACTION TIMES FOR CORRECT RESPONSES BY BLOCK
(IN MSEC)

	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
BLOCK 1	4882	(1702)	5347	(2352)	5115	(1886)
BLOCK 2	4569	(1520)	4100	(2214)	4334	(1522)
BLOCK 3	4343	(1754)	4365	(1774)	4354	(1567)
BLOCK 4	4348	(1192)	4591	(1607)	4470	(1169)
BLOCK 5	4176	(1149)	3945	(1489)	4060	(1066)
BLOCK 6	3822	(1104)	3899	(1408)	3860	(887)

APPENDIX A
TABLE A10

STUDY 3
FACE RECOGNITION REACTION TIME IN LVF AND RVF
REACTION TIMES FOR INCORRECT RESPONSES
(IN MSEC)

<u>N</u>	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
25	5142	(1500)	5336	(1715)	5239	(1572)

REACTION TIMES FOR INCORRECT RESPONSES BY BLOCK
(IN MSEC)

	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
BLOCK 1	6368	(3166)	6884	(4258)	6626	(3179)
BLOCK 2	4985	(1867)	5309	(2323)	5147	(2025)
BLOCK 3	4925	(1665)	4995	(1909)	4960	(1733)
BLOCK 4	4974	(1852)	5120	(1689)	5047	(1638)
BLOCK 5	5136	(1851)	5155	(2164)	5145	(1783)
BLOCK 6	4464	(1420)	4551	(1468)	4507	(1279)

APPENDIX A
TABLE A11

STUDY 4
ACCURACY IN LVF AND RVF ON FACE RECOGNITION

NUMBER OF INVERTED FACES CORRECTLY RECOGNIZED BY BLOCK

	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
BLOCK 1	4.6	(1.5)	5.2	(1.6)	9.9	(2.3)
BLOCK 2	5.1	(2.0)	5.1	(1.8)	10.2	(2.9)
BLOCK 3	5.4	(2.0)	5.8	(2.1)	11.2	(3.4)
BLOCK 4	6.0	(2.0)	6.3	(2.1)	12.4	(3.6)
BLOCK 5	6.5	(1.8)	6.1	(2.0)	12.6	(3.3)
BLOCK 6	7.0	(2.0)	6.7	(2.1)	13.7	(3.7)

APPENDIX A
TABLE A12

STUDY 4
FACE RECOGNITION REACTION TIME IN LVF AND RVF

REACTION TIMES FOR CORRECT RESPONSES BY BLOCK
(IN MSEC)

	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
BLOCK 1	5284	(2246)	5679	(2046)	5481	(1891)
BLOCK 2	4992	(2085)	4586	(1249)	4789	(1461)
BLOCK 3	4248	(1097)	4839	(1695)	4544	(1113)
BLOCK 4	4697	(1964)	4733	(1397)	4715	(1590)
BLOCK 5	4128	(1308)	4269	(1007)	4198	(984)
BLOCK 6	3994	(988)	4053	(927)	4023	(785)

APPENDIX A
TABLE A13

STUDY 4
FACE RECOGNITION REACTION TIME IN LVF AND RVF
REACTION TIMES FOR INCORRECT RESPONSES
(IN MSEC)

<u>N</u>	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
22	5193	(1390)	5321	(1576)	5257	(1408)

REACTION TIMES FOR INCORRECT RESPONSES BY BLOCK
(IN MSEC)

	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
BLOCK 1	6021	(2415)	5935	(2069)	5978	(2153)
BLOCK 2	5280	(1711)	5301	(1532)	5291	(1319)
BLOCK 3	4951	(1281)	4829	(1586)	4890	(1286)
BLOCK 4	5335	(2057)	5663	(3589)	5499	(2639)
BLOCK 5	4765	(1555)	4836	(1463)	4801	(1376)
BLOCK 6	4805	(1798)	5363	(2667)	5084	(1713)

APPENDIX A
TABLE A14
STUDY 5
ACCURACY IN LVF AND RVF ON FACE RECOGNITION

MEAN NUMBER OF INVERTED FACES CORRECTLY RECOGNIZED BY BLOCK

	<u>N</u>	<u>LVF</u>		<u>RVF</u>		<u>TOTAL</u>	
		MEAN	SD	MEAN	SD	MEAN	SD
BLOCK 1		4.3	(1.6)	4.6	(1.6)	8.9	(2.7)
BLOCK 2		4.7	(2.1)	4.8	(1.8)	9.5	(3.3)
BLOCK 3		4.9	(2.4)	6.0	(2.5)	10.9	(4.3)
BLOCK 4		5.6	(2.3)	5.9	(2.6)	11.5	(4.4)
BLOCK 5		6.2	(2.5)	6.3	(2.5)	12.5	(4.2)
BLOCK 6		6.5	(2.4)	6.4	(2.5)	12.9	(4.3)

APPENDIX A
TABLE A15

STUDY 5
SPEED IN LVF AND RVF ON FACE RECOGNITION

MEAN REACTION TIMES FOR CORRECT RESPONSES BY BLOCK
(IN MSEC)

	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
BLOCK 1	6105	(2844)	6050	(2782)	6077	(2526)
BLOCK 2	5522	(3161)	5797	(3297)	5660	(3171)
BLOCK 3	5678	(2489)	5882	(3171)	5780	(2703)
BLOCK 4	5021	(2484)	5881	(3116)	5451	(2733)
BLOCK 5	5077	(2474)	5196	(2567)	5136	(2423)
BLOCK 6	4731	(1761)	4082	(1499)	4407	(1567)

APPENDIX
TABLE A16

STUDY 5
SPEED IN LVF AND RVF ON FACE RECOGNITION
REACTION TIMES FOR INCORRECT RESPONSES
(IN MSEC)

<u>N</u>	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
22	5726	(2212)	5933	(2164)	5830	(2152)

MEAN REACTION TIMES FOR INCORRECT RESPONSES BY BLOCK
(IN MSEC)

	<u>LVF</u> MEAN	SD	<u>RVF</u> MEAN	SD	<u>TOTAL</u> MEAN	SD
BLOCK 1	5769	(1938)	6035	(1882)	5902	(1688)
BLOCK 2	5687	(2614)	5797	(2820)	5742	(2591)
BLOCK 3	5756	(2072)	6420	(3154)	6088	(2492)
BLOCK 4	5380	(2888)	6217	(2945)	5799	(2705)
BLOCK 5	5728	(3010)	6034	(2811)	5881	(2688)
BLOCK 6	6035	(2697)	5096	(2126)	5565	(2186)

APPENDIX B
DETAILED PROCEDURAL INFORMATION

INSTRUCTIONS TO SUBJECT FOR FACE RECOGNITION EXPERIMENT

Sit yourself comfortably in front of the keyboard with your chin in the chinrest. When ready to begin, press enter. You will see a flashing circle in the center of the screen. WHENEVER THIS APPEARS, YOU MUST LOOK DIRECTLY AT IT. DO NOT LOOK TO THE RIGHT OR THE LEFT.

Then you will see a face flash quickly on the screen. Then four faces will appear in a diamond arrangement. Choose the face that was flashed on the screen from among these four. Indicate your choice by pressing the corresponding arrow key. Use the pointer finger of your left hand to do this. DO NOT LEAN YOUR HAND ON THE KEYBOARD since this will produce keying errors.

The task is designed to be difficult, so do not feel frustrated. Don't worry too much about your response. If you are not sure, simply guess.

Occasionally, you will see a message to press enter to continue. If you wish to take a short rest before pressing enter, you may.

APPENDIX B

INSTRUCTIONS FOR AUDITORY SESSION

You will see the same flashing circle as before, then you will hear a voice speaking a single word. If you think that you have heard that same voice speaking that same word while you were looking at the faces, press the arrow key marked "yes". Otherwise, press the arrow key marked "no".

If the voice you hear is a new voice and a familiar or unfamiliar word, press "no". If the voice is a familiar voice speaking an unfamiliar word, also press "no". You should only press "yes" when the VOICE AND WORD COMBINATION ARE FAMILIAR.

APPENDIX B

POST SESSION QUESTIONS

Could you list any words you still remember?

Did you always see a flashing face after each circle?

How many different faces?

Were the faces always up there for the same length of time?

How did you decide which face to pick?

What percent of the time were you guessing?

Were any of the faces easier than others?

Did it get easier or harder as you went along?

How many different voices did you hear? (while looking at the faces)

When you heard the speech sound through the headphones, were you more conscious of the word, voice or equally aware of both?

Do you think there was there any connection between a face and a voice?

Do you have any other comments or observations?

APPENDIX B
FACE RECOGNITION EXPERIMENT
INFORMED CONSENT
ATTACHMENT 2

In this project you will be asked to do the following:

You will be asked to sit in front of a CRT with your chin in a chinrest.

You will be asked to wear a set of headphones.

You will be asked to fixate at a circle in the center of the screen.

A face will be quickly presented, then you will be given a multiple choice screen to pick which face you saw. You will indicate your choice by pressing a key.

There are no foreseen risks or immediate benefits to you as a result of your participation in this experiment. Your identity as a participant in this research will remain confidential with regard to any publication or oral presentation that might occur.

Your continued participation means that you are fully aware of the nature of this project and that you do agree to participate. You also understand that you may withdraw participation at any time. A copy of the Institutional Assurance file by the Research Foundation of CUNY is available for your inspection.

Do you have any questions?

Thank you for your consideration and cooperation.

I understand these instructions and the information provided, and do agree to participate in the research described.

SIGNATURE

DATE

APPENDIX C
SUMMARY OF NEW QUESTIONS

HEMISPHERIC ADVANTAGE AND FACE RECOGNITION

QUESTION 1

Is priming of the LH by speech processing responsible for the disappearance of the RH reaction time ADV and the alteration in the distribution of subjects, away from those with a RH ADV, observed in Studies 2 & 3 compared to Study 1?

QUESTION 2

Is the disappearance of a highly expert LH ADV which existed for processing silent upright faces due to interference caused by speech processing?

Questions 1 & 2 Possible Study:

Faces should be presented concurrently with some auditory stimulus which has not been shown to favor the LH (certain aspects of music, e.g.). If simultaneous priming and interference created by speech processing in the LH were actually responsible for the effects described in questions 1 & 2, then, in the presence of some other auditory stimulus, one might expect the continuance of the RH processing speed ADV. One would also expect the appearance of a LH ADV group in the concurrent processing situation with similar superior processing capabilities to that for silent faces, especially with continued high accuracy on face recognition in the LH.

QUESTION 3

There is evidence that the word component of the speech signal was more salient than the voice component. This, in combination with the fact that word is much more closely related to LH processing, raises the following question: Is it the processing of word alone which is producing the observed differences in relation to the LH ADV group, the distribution of subjects and the RH processing speed ADV?

APPENDIX C

SUMMARY OF NEW QUESTIONS (cont.)

Question 3 Possible Study

The same voice should be presented with each face so that the main aspect of the speech signal will be word. If under this scenario, there is no evidence of a difference in the measures described when compared to a combined word voice speech signal, then the answer to the above question is yes.

QUESTION 4

Can the suggested effects of speech processing, i.e. both priming and interference, be pushed further by actually drawing attention to speech?

Question 4 Possible Studies

Set up a true divided attention situation. Instruct subjects to attend to both the face task and the memorization of the speech stimuli. If the speech processing is truly driving the observed effects, one might expect a decline in accuracy in LH performance on faces, indicative of increased lateralized interference and perhaps greater numbers of subjects responding to faces more quickly in the LH as indicative of increased priming. Once a true divided attention situation is established, a task emphasis manipulation (Polson & Friedman, 1988) could be performed to try to establish the basis of the interference, i.e. management cost or direct use of the same resources.

QUESTION 5

Why did the LH ADV group go on to do better at speech? Why was this only the case for upright faces and speech (trend in same direction for upright & unrelated), but not for inverted faces and speech?

QUESTION 6

What is the meaning of having a LH or RH processing speed advantage?

Question 6 Possible Study

Follow those individuals with a LH ADV and a RH ADV from the silent face processing situation to the situation of processing faces and speech. Do they maintain the same advantage? What sort of patterns emerge?

APPENDIX C
SUMMARY OF NEW QUESTIONS (cont.)

FACE AND SPEECH RECOGNITION PERFORMANCE

QUESTION 1

If the special nature of the speech face combination is not responsible for being able to do two things at once, what is? Is the timing of the concurrence allowing the parallel processing to occur?

Question 1 Possible Study

Alter the concurrence from being an encoding one to include concurrent encoding of the speech signal with the decision process and output stage of the face processing. If the answer to question 1 is yes, then there should be a performance decrement in this altered scenario.

QUESTION 2

Does the extreme saliency of words allow them to be successfully co-processed with other visuospatial stimuli besides faces?

Question 2 Possible Study

Alter the task so that it involves lateralized recognition of some other visuospatial stimuli, e.g. tables, houses or landscapes simultaneously with incidental processing of speech. If the answer to question 2 is yes, then there should not be a performance decrement in this condition either.

QUESTION 3

Is the particular balance between attention drawn to a difficult task involving degraded stimuli and incidental learning of a naturalistic, highly salient stimulus responsible for the simultaneous processing of face and voice without performance decline?

Question 3 Possible Study

Instructionally divide attention by forewarning the participants about the speech and the speech recognition task (same suggested study as for question 4 under hemispheric advantage). If the answer to question 3 is yes, then there should now be a decline in performance.

APPENDIX C
SUMMARY OF NEW QUESTIONS (cont.)

ASSOCIATION OF FACE AND SPEECH

QUESTION 1

What is the effect on hemispheric lateralization of processing associated speech and face? This is not a new question, but it remains unanswered from these studies.

Question 1 Possible Studies

One possibility would be to make the relationship so clear that the association would unavoidably be made, e.g. by using very dissimilar voices. Another, perhaps superior, method would be to directly test whether a speech/face association had been made by including a post test of target speech/face combinations and distractor combinations. Subjects could then be divided into those who did and who did not successfully make the association. Patterns of performance and hemispheric laterality could be separately examined for these groups.

QUESTION 2

When it is known for certain that an association between face and speech has been made, does the pattern of hemispheric lateralization change over time?

If the RH is truly more involved in processing a relationship between face and speech, in the case where an association has been learned, it might be expected that a RH advantage might develop or be strengthened over time.

QUESTION 3

What happens to hemispheric lateralization when upright faces and speech are related, but voice is the only speech component available for processing?

APPENDIX C
SUMMARY OF NEW QUESTIONS (cont.)

Question 3 Possible Study

This could be explored by presenting faces with unique related voices but having all of the voices say the same thing. Since it is the voice that is involved in recognition of an individual, if the RH is more involved in processing the face voice connection than the left, it would be expected that manifestations of superior RH processing would increase in this situation. Similar to what is discussed in relation to question 2, it might also be expected that an effect of time, i.e. learning the association, would be evident.

QUESTION 4

Is the RH more involved in processing the association between speech and faces than the LH? Is it more involved in bimodal recognition of individuals?

APPENDIX C
SUMMARY OF NEW QUESTIONS (cont.)

FACE INVERSION

QUESTION 1

Is the inversion effect confounded with task complexity?

Question 1 Possible Study

It would be interesting to explore this issue further by comparing lateralized performance in the following four conditions:

1. processing upright lateralized faces
2. processing inverted lateralized faces
3. processing inverted lateralized faces manipulated so that they are equally as difficult as the upright ones
4. processing lateralized upright faces that have been manipulated in the same way as the faces in condition 3.

QUESTION 2

Why do the relationships between speed and accuracy on face performance only emerge for the processing of upright faces?

APPENDIX D
FEMALE AND MALE DATA: STUDIES 1-3

TABLE D1
STUDY 1, STUDY 2 AND STUDY 3

INDIVIDUALS GROUPED BY SEX

ACCURACY IN LVE AND RVE ON FACE RECOGNITION
NUMBER OF FACES CORRECTLY RECOGNIZED

	<u>N</u>	<u>LVE</u> <u>MEAN</u>	<u>SD</u>	<u>RVE</u> <u>MEAN</u>	<u>SD</u>	<u>TOTAL</u> <u>MEAN</u>	<u>SD</u>
<u>STUDY 1</u>							
FEMALE	18	33.6	(10.9)	35.8	(12.8)	69.4	(22.3)
MALE	7	36.4	(5.6)	31.7	(7.2)	68.1	(10.2)
<u>STUDY 2</u>							
FEMALE	19	34.2	(6.5)	33.2	(6.4)	67.3	(12.3)
MALE	6	29.3	(6.2)	32.2	(8.6)	61.5	(13.2)
<u>STUDY 3</u>							
FEMALE	19	32.9	(8.5)	31.6	(8.0)	64.6	(14.1)
MALE	6	31.7	(8.9)	30.5	(8.1)	62.2	(15.4)

NOTE: STUDY 1 ANOVA
sex by visual field interaction: $F(1,21)=5.48$, $p<.03$

APPENDIX D

TABLE D2
STUDY 1, STUDY 2 AND STUDY 3

INDIVIDUALS GROUPED BY SEX

FACE RECOGNITION REACTION TIME IN LVE AND RVE
REACTION TIMES FOR CORRECT RESPONSES
(IN MSEC)

	<u>N</u>	<u>LVE</u> MEAN	SD	<u>RVE</u> MEAN	SD	<u>TOTAL</u>
<u>STUDY 1</u>						
FEMALE	18	4063	(1166)	4388	(1506)	4226 (1253)
MALE	7	4598	(1503)	5068	(1300)	4833 (1394)
<u>STUDY 2</u>						
FEMALE	19	4680	(1364)	4618	(1335)	4649 (1320)
MALE	6	4621	(1106)	5339	(2528)	4980 (1745)
<u>STUDY 3</u>						
FEMALE	19	4372	(985)	4424	(1510)	4398 (1209)
MALE	6	4308	(712)	4217	(482)	4263 (434)

NOTES:

STUDY 1 ANOVA

sex: $F(1,21)=3.39$, $p=.08$

STUDY 2 ANOVA

sex by visual field intereaction : $F(1,21)=3.51$, $p<.08$

REFERENCES

- Bever, T.G. & Chiarello, R. (1974). Cerebral dominance in musicians and non-musicians. Science, 185, 537-539.
- Bruning, J.L. & Kintz, B.L. (1977). Computational Handbook of Statistics 2nd Ed.. Glenview, IL: Scott, Foresman and Company.
- Bryden, M.P. (1977). Measuring handedness with questionnaires. Neuropsychologia, 15, 617-624.
- Bryden, M.P. (1982). Laterality: Functional Asymmetry in the Intact Brain. New York: Academic Press.
- Buchanan, D.C. (1989). Changes in hemispheric advantage during familiarization with facial stimuli: influence of sex and handedness. Unpublished Ph.D. dissertation: City University of New York.
- Campbell, R. (1989). Lipreading. In A.W. Young & H.D. Ellis (Eds.), Handbook of Research on Face Processing (pp. 187-206). Amsterdam - New York - Oxford - Tokyo: Elsevier Science Publishers B.V. (North-Holland).
- Corina, D.P., Vaid, J., & Bellugi, U. (1992). The linguistic basis of left hemisphere specialization. Science, 255, 1258-1260.
- De Casper, A.J. & Spence, M.J. (1986). Prenatal maternal speech influences newborns' perception of speech sounds. Infant Behavior and Development, 9(2), 133-150.
- De Schonen, S., Dereuelle, C., Mancini, J. & Pascalis, O. (1993). Hemispheric difference in face processing and brain maturation. In Benedicte de Boysson-Bardies, Scania de Schonen, Peter Jusczyk, Peter McNeilage, & John Morton (Eds.), Developmental Neurocognition: Speech and Face Processing in the first Year of Life (pp. 149-163). Dordrecht/Boston/London: Kluwer Academic Publishers.
- De Schonen, S. & Mathivet, E. (1989). First come, first served: a scenario about the development of hemispheric specialization in face recognition during infancy. European Bulletin of Cognitive Psychology, 9(1), 3-44.

- Edwards, A.L. (1960). Experimental Design in Psychological Research. New York: Rinehart.
- Ellis, A. W. (sic) (1989). Neuro-cognitive processing of faces and voices. In A.W. Young & H.D. Ellis (Eds.), Handbook of Research on Face Processing (pp. 207-216). Amsterdam - New York - Oxford - Tokyo: Elsevier Science Publishers B.V. (North-Holland).
- Ellis, H. D. & Young, A. W. (1989). Are faces special? In A.W. Young & H.D. Ellis (Eds.), Handbook of Research on Face Processing (pp. 1-26). Amsterdam - New York - Oxford - Tokyo: Elsevier Science Publishers B.V.
- Farah, M.J. (1995). What causes the face inversion effect? Journal of Experimental Psychology Human Perception and Performance, 21(3), 628-634.
- Farah, M.J. (1995, February). The neural basis of face and object recognition in humans. Paper presented at the University Seminar on the Psychobiology of Animal Cognition, New York, NY.
- Farah, M.J. (1995). Face perception and within-category discrimination in prosopagnosia. Neuropsychologia, 33(6), 661-674.
- Friedman, A. & Polson, M.P. (1981). Hemispheres as independent resource systems: limited capacity processing and cerebral specialization. Journal of Experimental Psychology, 7, 1031-1058.
- Gazzaniga, M.S. (1987). Perceptual and attentional processes following callosal section in humans. Neuropsychologia, 25(1A), 119-133.
- Green, A. & Vaid, J. (1986). Methodological issues in the use of the concurrent activities paradigm. Brain and Cognition, 5, 465-476.
- Hiscock, Merrill (1988). Behavioral asymmetries in normal children. In Dennis L. Molfese & Sidney J. Segalowitz (Eds.), Brain Lateralization in Children: Developmental Implications (pp. 85-169). New York: Guilford Press.

- Hugdahl, K., Iverson, P.A. & Johnsen, B.H. (1993). Laterality for facial expressions: does the sex of the subject interact with the sex of the stimulus face? Cortex, 29, 325-331.
- Kellogg, R.T. & Dare, R.S. (1989). Explicit memory for unattended information. Bulletin of the Psychonomic Society, 27(5), 409-412.
- Kinsbourne, M., (1975). The mechanism of hemispheric control of the lateral gradient of attention. In P.M.A. Rabbit & S. Dornic (Eds), Attention & Performance, V (pp. 81-97). London; New York; San Francisco: Academic Press.
- Kinsbourne, M. & Byrd, M., (1985). Word load and visual hemifield shape recognition: priming and interference effects. In M.I. Posner & O.S. Marin (Eds.), Mechanisms of attention. Attention and performance, XI (pp. 529-543). Hillsdale, N.J.: Erlbaum.
- Kinsbourne, M. & Cook, J. (1971). Generalized and lateralized effects of concurrent verbalization on a unimanual skill. Quarterly Journal of Experimental Psychology, 23, 341-345.
- Kinsbourne, M. & Hiscock, M., (1983). Asymmetries of dual-task performance. In Joseph B Hellige (Ed.), Cerebral Hemisphere Asymmetry Method, Theory and Application (pp. 255-334). New York: Praeger Publishers.
- Kittler, P., Turkewitz, G., & Goldberg, E. (1989). Shifts in hemispheric advantage during familiarization with complex visual patterns. Cortex, 25, 27-32.
- Klein, D. Moscovitch, M. & Vigna, C. (1976). Attentional mechanisms and perceptual asymmetries in tachistoscopic recognition of words and faces. Neuropsychologia, 14, 55-66.
- Kuhl, P.K. & Meltzoff, A.N. (1984). The intermodal representation of speech in infants. Infant Behavior and Development, 7, 361-381.

- Levine, S. C. (1989). The question of faces: Special is in the brain of the beholder. In A.W. Young & H.D.Ellis (Eds.), Handbook of Research on Face Processing (pp. 37-48). Amsterdam - New York - Oxford - Tokyo: Elsevier Science Publishers B.V. (North-Holland).
- Levine, S. C., Banich, M. T., & Koch-Weser, M. (1984). Variations in patterns of lateral asymmetry among dextrals. Brain and Cognition, 3, 317-334.
- MacKain, K., Studdert-Kennedy, M., Spieker, S., & Stern, D. (1983). Infant intermodal speech perception is a left-hemisphere function. Science, 219, 1347-1349.
- McFarland, R. & Kennison, R.F. (1988). Asymmetrical effects of music upon spatial-sequential learning. Journal of General Psychology, 115(3), 263-272.
- Melara, R.D., Dewitt-Rickards, T.S., & O'Brien, T.P. (1989). Enhancing lineup accuracy: two codes are better than one. Journal of Applied Psychology, 74(5), 706-713.
- Morton, J. (1993). Mechanisms in infant face processing. In Benedicte de Boysson-Bardies, Scania de Schonen, Peter Jusczyk, Peter McNeilage, & John Morton (Eds.), Developmental Neurocognition: Speech and Face Processing in the first Year of Life (pp. 93-102). Dordrecht/Boston/London: Kluwer Academic Publishers.
- Morton, J. & Johnson, M.H. (1991). CONSPEC and CONLERN: A two process theory of infant face recognition. Psychological Review, 98(2), 164-181.
- Morton, J & Johnson, M.H. (1989). Four ways for faces to be 'special'. In A.W. Young & H.D.Ellis (Eds.), Handbook of Research on Face Processing (pp. 49-56). Amsterdam - New York - Oxford - Tokyo: Elsevier Science Publishers B.V. (North-Holland).
- Moscovitch, M. (1986). Afferent and efferent models of visual perceptual asymmetries: theoretical and empirical implications. Neuropsychologia, 24(1), 91-114.

- Paivio, A. (1966). Latency of verbal associations and imagery to noun stimuli as a function of abstractness and generality. Canadian Journal of Psychology, 20(4), 379-387.
- Paivio, A. (1968). A factor-analytic study of word attributes and verbal learning. Journal of Verbal Learning and Verbal Behavior, 7, 41-49.
- Pashler, H. (1990). Do response modality effects support multiprocessor models of divided attention? Journal of Experimental Psychology: Human Perception and Performance, 16(4), 826-842.
- Polson, M.C. & Friedman, A. (1988). Task-sharing within and between hemispheres: a multiple-resources approach. Human Factors, 30(5), 633-643.
- Reinitz, M.T., Morrissey, J. & Demb, J. (1994). Role of attention in face encoding. Journal of Experimental Psychology: Learning Memory and Cognition, 20(1), 161-168.
- Reuter-Lorenz, P.A., Kinsbourne, M. & Moscovitch, M. (1990). Hemispheric control of spatial attention. Brain and Cognition, 12, 240-266.
- Rizzolatti, G. & Buchtel, H.A. (1977) Hemispheric superiority in reaction time to faces: a sex difference. Cortex, 13, 300-305. Abstract from: Silverplatter File: Psychlit Item: 61-02846.
- Rolandelli, R., Wright, J.C., Huston, A.C. & Eakins, D. (1991). Children's auditory and visual processing of narrated and nonnarrated television programming. Journal of Experimental Child Psychology, 51, 90-122.
- Rose, R.A. & Ruff, H.A.. (1987). Cross-modal abilities in human infants. In J.D. Osofsky (Ed.), Handbook of Infant Development (2nd ed., pp. 318-362). New York: Wiley & Sons.

- Ross, P. and Turkewitz, G. (1981). Individual differences in cerebral assymetries for facial recognition. Cortex, 17, 199-214.
- Ross, P. and Turkewitz, G. (1982). Changes in hemispheric advantage in processing facial information with increasing stimulus familiarization. Cortex, 18, 489-499.
- Ross-Kossak, P. & Turkewitz, G. (1986). A micro and macro developmental view of the nature of changes in complex information processing: a consideration of changes in hemispheric advantage during familiarization. In R. Bruyer (Ed.), The Neuropsychology of Face Perception and Facial Expression. Hillsdale, NJ: Lawrence Erlbaum.
- Sacks, O. (1989). Seeing Voices A Journey into the World of the Deaf. Berkeley/Los Angeles: University of California Press.
- Schriefers, H. & Meyer, A.S. (1990). Experimental note: cross-modal, visual auditory picture-word interference. Bulletin of the Psychonomic Society, 28(5), 418-420.
- Sergent, J. (1983). Role of the input in visual hemispheric assymetries. Psychological Bulletin, 93(3), 481-512.
- Sergent, J. (1987). Information processing and laterality effects for object and face perception. In Glyn W. Humphreys & M. Jane Riddoch (Eds.), Visual Object Processing: A Cognitive Neuropsychological Approach. Hove, England: Lawrence Erlbaum Associates, Inc.
- Sergent, J. (1989). Structural processing of faces. In A.W. Young & H.D. Ellis (Eds.), Handbook of Research on Face Processing (pp. 57-91). Amsterdam: Elsevier Science Publishers B.V.
- Slater, A. (1993). Visual Perceptual Abilities at birth: Implication for face perception. In Benedicte de Boysson-Bardies, Scania de Schonen, Peter Jusczyk, Peter McNeilage, & John Morton (Eds.), Developmental Neurocognition: Speech and Face Processing in the first Year of Life (pp. 125-134). Dordrecht/Boston/London: Kluwer Academic Publishers.

- Sprott, D.A. & Bryden, M.P. (1983). Measurement of laterality effects. In Hellige, J.B. (Ed), Cerebral Hemisphere Asymmetry Method Theory and Application (pp. 444-464). New York: Praeger.
- Springer, S.P. and Deutsch, G. (1989). Left Brain, Right Brain. New York: W.H. Freeman and Company.
- Stanislaw, H. (1988). Methodological considerations for the study of multimodal signal detection. Perception & Psychophysics, 44(6), 541-550.
- Stine, E.A.L., Wingfield, A. & Myers, S.D. (1990). Age differences in processing information from television news: the effects of bisensory augmentation. Journal of Gerontology, 45(1), P1-8.
- Turkewitz, G. (1988). A prenatal source for the development of hemispheric specialization. In Dennis L. Molfese & Sidney J. Segalowitz (Eds.), Brain Lateralization in Children: Developmental Implications (pp. 73-81). New York: Guilford Press.
- Turkewitz, G. (1989). Face processing as a fundamental feature of development. In A.W. Young & H.D. Ellis (Eds.), Handbook of Research on Face Processing (pp. 401-404). Amsterdam: Elsevier Science Publishers B.V.
- Turkewitz, G. (1990). Perinatal influences on the development of hemispheric specialization and complex information processing. In M. J. Weiss & R.R. Zelazo (Eds.), Infant Attention (pp. 443-465). Norwood, NJ: Ablex.
- Turkewitz, G., Lewkowicz, D.J., & Gardner, J.M. (1983). Determinants of infant perception. In J.S. Rosenblatt, R.A. Hinde, C. Beer, & M.C. Bushnel (Eds.), Advances in the Study of Behavior (Vol. 13, pp.39-62). New York: Academic Press.
- Turkewitz, G. & Ross, P. (1983). Changes in visual field advantage for facial recognition: the development of a general processing strategy. Cortex, 19, 179-185.

- Umiltà, C., Brizzolara, D., Tabossi, P., & Fairweather, H. (1978). Factors affecting face recognition in the cerebral hemispheres: familiarity and naming. In J. Requin (Ed.), Attention and Performance, VII (pp. 363-374). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Umiltà, C., Rizzolatti, G., Anzola, G.P., Luppino, G. & Porro, C. (1985). Evidence of interhemispheric transmission in laterality effects. Neuropsychologia, 23 (2), 203-213.
- Uecker, A. and Obrzut, J.E. (1993). Hemisphere and gender differences in mental rotation. Brain & Cognition, 22, 42-50.
- Van Lancker, D.R. & Canter, G.J. (1982). Impairment of voice and face recognition in patients with hemispheric damage. Brain & Cognition, 1, 185-195.
- Wagenaar, W.A., Varey, C.A., & Hudson, P.T.W. (1984). Do audiovisuals aid? A study of bisensory presentation on the recall of information. In H. Bouma & D.G. Bouwhuis (Eds.), Attention and Performance, X: Control of Language Processes (pp. 379-391). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Williams, B. (1993). GETFACES. (Turbo Pascal 6). New York: Bruce Williams.
- Williams, B. (1994). PSY3SND. (Turbo Pascal 6). New York: Bruce Williams.