

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

Order Number 9510666

**An examination of syntagmatic and paradigmatic associations
using behavioral and electrophysiological measures of priming
tasks**

Gomes, Hilary Thompson, Ph.D.

City University of New York, 1994

Copyright ©1994 by Gomes, Hilary Thompson. All rights reserved.

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

A

AN EXAMINATION OF SYNTAGMATIC AND PARADIGMATIC ASSOCIATIONS
USING BEHAVIORAL AND ELECTROPHYSIOLOGICAL MEASURES OF
PRIMING TASKS

by
HILARY THOMPSON GOMES

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

1994

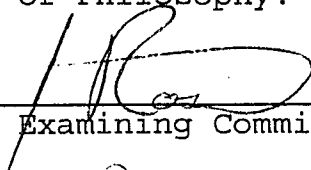
© 1994

HILARY THOMPSON GOMES

All rights reserved

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.

6/1/94
Date


Chair of Examining Committee

6/2/94
Date


Executive Officer

Jeffrey J. Rosen, Ph.D.

Walter Ritter, Ph.D.

Vivien C. Tartter, Ph.D.

David Friedman, Ph.D.

Katherine Nelson, Ph.D.

William M. Dince, Ph.D.

Supervisory Committee

THE CITY UNIVERSITY OF NEW YORK

Abstract**AN EXAMINATION OF SYNTAGMATIC AND PARADIGMATIC ASSOCIATIONS
USING BEHAVIORAL AND ELECTROPHYSIOLOGICAL MEASURES OF
PRIMING TASKS**

by

HILARY THOMPSON GOMES**Advisor: Professor Jeffrey J. Rosen**

Free association tasks have revealed a developmental shift from syntagmatic to paradigmatic responding (Entwistle, 1966; Nelson, 1977). Children tend to generate syntagmatic responses (e.g., "dog" - "bark") while adults generally produce paradigmatic responses (e.g., "dog" - "cat"). Word associations are thought to reflect semantic organization so this change in response behavior has been interpreted as a semantic reorganization.

These experiments examined adult syntagmatic and paradigmatic associations using behavioral priming and electrophysiological (N400) measures. It was hypothesized that both types of associations would be evident but that paradigmatic associations would be stronger explaining the adult paradigmatic response bias in word associations.

Experiments 1 - 5 were methodological studies designed to determine optimal experimental parameters for examining these hypotheses. Experiments 6 - 9 addressed theoretical issues. Experiment 6, a lexical decision study, compared behavioral priming and its generality across prime/target association type (syntagmatic and paradigmatic), grammatical class of the prime (noun and adjective), presentation modality (visual and auditory) and SOA (650 and 1150 msec). Priming was significant for all comparisons, except the visual noun paradigmatic (both SOAs) and the visual adjective syntagmatic conditions (1150 SOA). Unexpectedly, there was not a main effect of association type but an interaction of association type and grammatical class. Experiments 8 and 9 attempted to generalize these findings across SOA and word order. Their results generally supported and replicated those of Experiment 6.

Experiment 7, a word probe study, examined N400 effects. The N400 effect was compared across association type, grammatical class and modality. Significant N400 effects were found for all conditions, except auditory adjective paradigmatic. No differences were found due to grammatical class or association type, and, unlike Experiment 6, no interaction was found.

The behavioral and N400 results were then compared and their implications for adult and developmental models of semantic organization were discussed.

ACKNOWLEDGEMENTS

This dissertation would not have been possible without the help, guidance, and support of a number of people. Their willingness to engage in this process has meant a tremendous amount to me!!!

First, I want to thank my mentor, Jeff Rosen. For the past six years he has patiently and insightfully helped me to develop the ideas underlying this dissertation. Throughout that time, he continually challenged me to search for weaknesses in my theoretical interpretations of the literature and of my data, and when I would find them, he would work with me until we could create stronger alternatives. He has been a wonderful and constantly challenging mentor and I will always be grateful that I had the opportunity to work closely with him.

I want to express my thanks to Walter Ritter for introducing me to ERPs. This dissertation has an ERP component because of his ability to convey his excitement and fascination with ERPs and his willingness to share his expert knowledge. I also thank him for the endless hours he spent going over my data and for his ability to see the patterns in the ERPs.

I am grateful to Vicky Tartter for her untiring willingness to carefully read yet another draft of the dissertation, for her ability to view the data from various theoretical perspectives and to suggest alternative explanations, and for her support, encouragement and belief that I could complete the dissertation and actually do I good job.

I also wish to thank my outside readers, Katherine Nelson for her infectious curiosity about developmental processes, Dave Friedman for his insights into electrophysiological research with adults and children, and Bill Dince for helping me design the second year research project which developed into this dissertation and for the many times that his help allowed me to find the next step and continue the process.

In addition to my committee, I received invaluable help from a number of other people, particularly Diane Kurtzberg, Judy Kreuzer, Molly Schroeder, John Foxe, and Michelle Dunn. They taught me the process and the details of electrophysiological research and were infinitely patient with my daily questions and crises.

I would like to thank all my family and friends who have shared my emotional roller coaster throughout this

process and have helped me to keep some perspective. Thanks especially to my sister, Valerie Gomes, to my friends, Sylvie Goldman, Judith Peterson, Marisa Human, and Paula McKinley, and to my grandparents, Florence and Ed Gomes, Sr.

I want to express special thanks to my parents, Pam and Ed Gomes, Jr., for being my first and most important teachers, and for loving me and believing in me unconditionally as I learned their's and life's lessons.

Finally, I want to express my deepest appreciation to my most critical editor and my best friend, my husband Chris Christodoulou. We made it!

TABLE OF CONTENTS

I. INTRODUCTION	1
A. Adult Models of Semantic Memory	2
A1. Network Models	4
Hierarchical-Network Model	5
Spreading-Activation Model	8
A2. Feature Models	10
Feature Comparison Model	10
Property Comparison Model	12
B. The Syntagmatic/Paradigmatic Shift -	
Word-Association Data	14
C. Nelson's Developmental Model of Semantic Memory .	23
D. Aphasia	31
E. Methodological Approaches	39
E1. Priming	41
E2. Evoked Potentials - N400	44
F. Rationale	50
II. METHODOLOGICAL STUDIES	52
A. EXPERIMENT 1 - Long SOA Semantic Decision	53
A1. Method	53
Subjects	53
Stimuli	53
Procedure	56
Data Analysis	57
A2. Results and Discussion	57
Error Data	57
Reaction Time Data	58
B. EXPERIMENT 2 - Short SOA Semantic Decision . . .	60
B1. Method	60
Subjects	60
Stimuli	61
Procedure	61
Data Analysis	61
B2. Results and Discussion	61
Error Data	61
Reaction Time Data	62
C. EXPERIMENT 3 - Blocked, Short SOA	
Semantic Decision	64
C1. Method	64
Subjects	64
Stimuli	65
Procedure	65
Data Analysis	65
C2. Results and Discussion	65
Error Data	65
Reaction Time Data	66
D. EXPERIMENT 4 - Short SOA Lexical Decision . . .	67
D1. Method	67
Subjects	67
Stimuli	68

Procedure	68
Data Analysis	68
D2. Results and Discussion	69
Error Data	69
Reaction Time Data	69
E. EXPERIMENT 5 - Letter-Probe Evoked Potential	71
E1. Method	71
Subjects	71
Stimuli	72
Procedure	73
EEG Recording Procedure	74
Data Analysis	75
E2. Results and Discussion	75
Error Data	75
Evoked Potential Data	76
F. General Discussion of Methodological Studies	79
III. THEORETICAL STUDIES	82
A. EXPERIMENT 6 - Visual and Auditory	
Lexical Decision	82
A1. Method	83
Subjects	83
Stimuli	84
i. Non-cued Lexical Decision Pilot	84
ii. Cued Lexical Decision - Visual	
Stimuli	87
iii. Cued Lexical Decision -	
Auditory Stimuli	92
Procedure	96
Data Analysis	98
A2. Results and Discussion	98
Error Data - Visual Paradigm	98
Error Data - Auditory Paradigm	99
Reaction Time Data - Visual Paradigm	100
Reaction Time Data - Auditory Paradigm	105
Reaction Time Data - Visual Paradigm	
versus Auditory Paradigm	109
B. EXPERIMENT 7 - Word-Probe, Visual and Auditory	
Evoked Potential	113
B1. Method	115
Subjects	115
Stimuli	116
i. Visual Stimuli	116
ii. Auditory Stimuli	117
Procedure	119
EEG Recording Procedure	119
Data Analysis	122
B2. Results and Discussion	124
Word-Probe Data	124
N400 Data - Visual Paradigm	124
N400 Data - Auditory Paradigm	130

N400 Data - Visual Paradigm versus Auditory Paradigm	135
C. EXPERIMENT 8 - Auditory, 1150 SOA,	
Lexical Decision	137
C1. Method	138
Subjects	138
Stimuli	138
Procedure	139
Data Analysis	139
C2. Results and Discussion	140
Error Data	140
Reaction Time Data - Experiment 7 Stimuli	140
Reaction Time Data - Experiment 6 Stimuli	143
D. EXPERIMENT 9 - Reversed, 650 SOA	
Lexical Decision	147
D1. Method	147
Subjects	147
Stimuli	147
Procedure	148
Data Analysis	148
D2. Results and Discussion	149
Error Data	149
Reaction Time Data	149
E. General Discussion of Theoretical Studies	151
E1. Behavioral Hypotheses	151
E2. Electrophysiological Hypotheses	163
IV. GENERAL DISCUSSION	167
A. The Grammatical Class/Association Type Interactions	168
B. Summary of Results and Discussion	176
C. Future Studies	179
Appendix A	182
Appendix B	184
Appendix C	186
Appendix D	188
Appendix E	192
Appendix F	193
References	202

LIST OF TABLES

1.	Percentage of paradigmatic responses in a word-association task. Adapted from Entwisle (1966)	16
2.	Mean number of responses on a word-association task by category by age. Adapted from Lucariello, Kyratzis, and Nelson (1992)	28
3.	Experiment 1. Average reaction times and priming in msec.	58
4.	Experiment 1. Average reaction times and priming in msec for the defined subset of stimuli.	59
5.	Experiment 2. Average reaction times and priming in msec.	62
6.	Experiment 3. Average reaction times and priming in msec.	66
7.	Experiment 4. Average reaction times and priming in msec.	70
8.	Experiment 5. Mean amplitudes in uV at Cz.	76
9.	Experiment 5. The N400 effect in uV by SOA at Cz.	77
10.	Experiment 5. Mean peak latency in msec at Cz.	77
11.	The characteristics of the visual noun prime stimuli and the between-group comparisons of those characteristics.	88
12.	The characteristics of the visual adjective prime stimuli and the between-group comparisons of those characteristics.	89
13.	The characteristics of the auditory noun prime stimuli and the between-group comparisons of those characteristics.	93
14.	The characteristics of the auditory adjective prime stimuli and the between-group comparisons of those characteristics.	94
15.	Experiment 6. Average reaction times and priming in msec in the visual paradigm by condition.	101
16.	Experiment 6. Average reaction times and priming in msec in the auditory paradigm by condition.	106

17. Experiment 6. Average reaction times and priming in msec in the visual and auditory paradigms for the 650 SOA. 111
18. Experiment 7. The N400 effect in uV by electrode by condition for the visual paradigm. 125
19. A comparison of the visual N400 effect in uV (at Cz) from Experiment 7 and the visual priming in msec from Experiment 6 for the 1150 SOA. 129
20. Experiment 7. The N400 effect in uV by electrode by condition for the auditory paradigm. 131
21. Experiment 7. The N400 effect in uV (at Cz) for the visual and auditory paradigms. 136
22. A comparison of the auditory N400 effect in uV (at Cz) from Experiment 7 and the auditory priming in msec from Experiment 8 for the 1150 SOA. 142
23. A comparison of the auditory priming in msec for the 650 SOA from Experiment 6 and for the 1150 SOA from Experiment 8. 145
24. A comparison of the auditory priming in msec from Experiment 6 and from Experiment 9. 150

LIST OF FIGURES

1.	An illustration of the Collins and Quillian (1969) Hierarchical-Network Model	7
2.	A schematic representation of the Collins and Loftus (1975) Spreading-Activation Model.	9
3.	An example of concepts in the Smith, Shoben and Rips (1974) Feature Comparison Model.	11
4.	An example of a general Event Representation (Nelson, 1985) for taking a bath.	24
5.	Holcomb and Neville's (1990) grand mean evoked potentials to related and unrelated target words for the visual and auditory modalities.	49
6.	Experiment 5. Grand mean evoked potentials recorded at Cz for the 5 subjects with the 2100 msec epoch. . .	78
7.	Experiment 6. Two graphs of visual priming by SOA, grammatical class of the prime and association type.	103
8.	Experiment 6. A graph of auditory priming by grammatical class of the prime and association type.	108
9.	Recording electrodes.	121
10.	Experiment 7. Grand mean evoked potentials elicited in the four visual conditions.	126
11.	Experiment 7. Grand mean evoked potentials elicited in the four auditory conditions.	132
12.	An example of a bipolar adjective pair in the Miller and Fellbaum (1991) organizational model.	172

I. INTRODUCTION

One of the central issues in psychology and philosophy is the nature of meaning. Meaning systems enable us to represent not only concrete, currently present objects, but also unseen and imaginary objects, as well as abstract and novel ideas. Psychologists' investigations into meaning have focused on the acquisition, development, organization and representation of language-based meaning systems. In cognitive psychology, the study of linguistic meaning is typically examined through the study of semantic memory.

Most investigations of semantic memory have been concerned with the organization and representation of linguistic meaning in normal adults. This dissertation examines the organization of semantic memory from a developmental perspective and argues that there are two systems in development and in adult processing: the first to process sequential, grammatically constrained, thematic information (e.g., "the dog barked") and the second to process categorical or associative relations (e.g., "dog"- "cat").

The background and rationale for this investigation are presented as follows. First, several adult models of semantic memory will be described. Second, a developmental

shift from sequential to categorical response behavior, which cannot be accounted for by the adult models, will be discussed. Third, a model of semantic development and organization, which can account for this shift, will be presented as an alternative to the standard adult models. Fourth, the neuropsychological data from aphasic patients will be examined to characterize the partial dissociation of the categorical and sequential systems in semantic breakdown. Fifth, the use of two measures of semantic organization, semantic priming and N400 amplitude, will be described. Finally, we will integrate the earlier sections as a rationale for the current investigation in which behavioral and electrophysiological measures were recorded from normal adults during categorical and sequential priming tasks.

A. Adult Models of Semantic Memory

A variety of definitions of semantic memory have appeared in the literature. All of the definitions have described a knowledge or meaning-based memory system, but some have focused on linguistic meaning while others have focused on general knowledge. The former is exemplified by Tulving's (1972) original definition in which semantic memory was defined as:

the memory necessary for the use of language. It is a mental thesaurus, organized knowledge a person possesses about words and other verbal symbols, their meaning and referents, about relations among them, and about rules, formulas, and algorithms for the manipulation of these symbols, concepts, and relations. (p. 386)

This is perhaps the most common definition, however, it excludes our nonlinguistic symbolic knowledge (e.g., our knowledge of music or math) and our prelinguistic symbolic knowledge (e.g., our knowledge about a concept before we have learned the correct label). From a developmental viewpoint this is a major omission, since it is generally believed that concept development in infants and young children begins before word learning (Nelson, 1985). A broader definition for semantic memory, such as "general knowledge of the world" (Baddeley, 1988, p. 180) or linguistic and non-linguistic symbolic knowledge, is considered more appropriate and will be used in this dissertation.

Contemporary models of the organization of semantic memory in normal adults have primarily dealt with interrelationships and groupings of nouns (i.e., names of objects), and attributes which distinguish between nouns

(for reviews see Chang, 1986; Smith, 1978). These models were designed to explain static, categorical associations, and as a result, do not adequately address non-categorical associations and have no explicit mechanisms for developmental change. There are two primary types of adult models. The first type, network models, have operationalized "organization" structurally as the connections between related concepts, primarily noun concepts. The second type, feature models, have operationalized "organization" computationally as the mathematical comparison of the features or attributes of the objects. Each model has been developed in an attempt to account better for some aspect of the experimental data.

A1. Network Models

In network models, classes of objects (e.g., "table" or "chair") or ideas (e.g., "freedom" or "democracy") are symbolized by nodes which are connected in a matrix fashion (as in a tree diagram). The connections between nodes define which words are associated and the strength of these associations. The network models assume that when a specific noun is activated by a language input, a "spread of activation" radiates from the activated node to adjacent nodes and then from these adjacent nodes to tertiary points, etc. (Chang, 1986; Collins & Quillian, 1969). The two

classic network models are the Collins and Quillian (1969) Hierarchical-Network Model and the Collins and Loftus (1975) Spreading-Activation Model, which was an elaboration of the original model. The parallel distributed processing models also fit into this category, but the majority of these models address word recognition, not semantic organization (Seidenberg & McClelland, 1989; Grossberg & Stone, 1986).

Hierarchical-Network Model (Collins and Quillian, 1969). In this model, nodes which represent concepts are hierarchically organized. For example, a node representing the category, "food", would be placed at the top, with nodes representing "fruit" and "dessert" as subsets underneath. Nodes representing "apple" and "tomato" would be subsets of "fruit" and nodes representing "ice cream" and "brownie" would be subsets of "dessert" (see Figure 1). These nodes are connected by an "is a" association (e.g., "an apple is a fruit"). It should be noted that this model is strictly hierarchical, so the "apple node" is not directly connected to the "food node", but must pass through the "fruit node" to reach the "food node". Property nodes, which define the specific characteristics of the nouns in the hierarchy, are associated with each of the nouns. These associations are of the form: "has" (e.g., "brownie has chocolate flavor"), "can" (e.g., "birds can sing"; it should be noted that this form is particularly important for animate nouns) and "is"

(e.g., "ice cream is cold"). The system is economical in that a property is stored with the most general noun. Nouns which are subsets of a specific node (e.g., apple) are assumed to have the properties of the higher level nodes (e.g., "is grown on trees") unless otherwise specified (e.g., "tomato is not grown on trees"). However, properties are sometimes linked to lower level nouns (e.g., "is sweet" might be linked to "brownie" as well as "dessert") when the noun is the first learned instance of a category or when the property is particularly important to the concept and frequently paired with it.

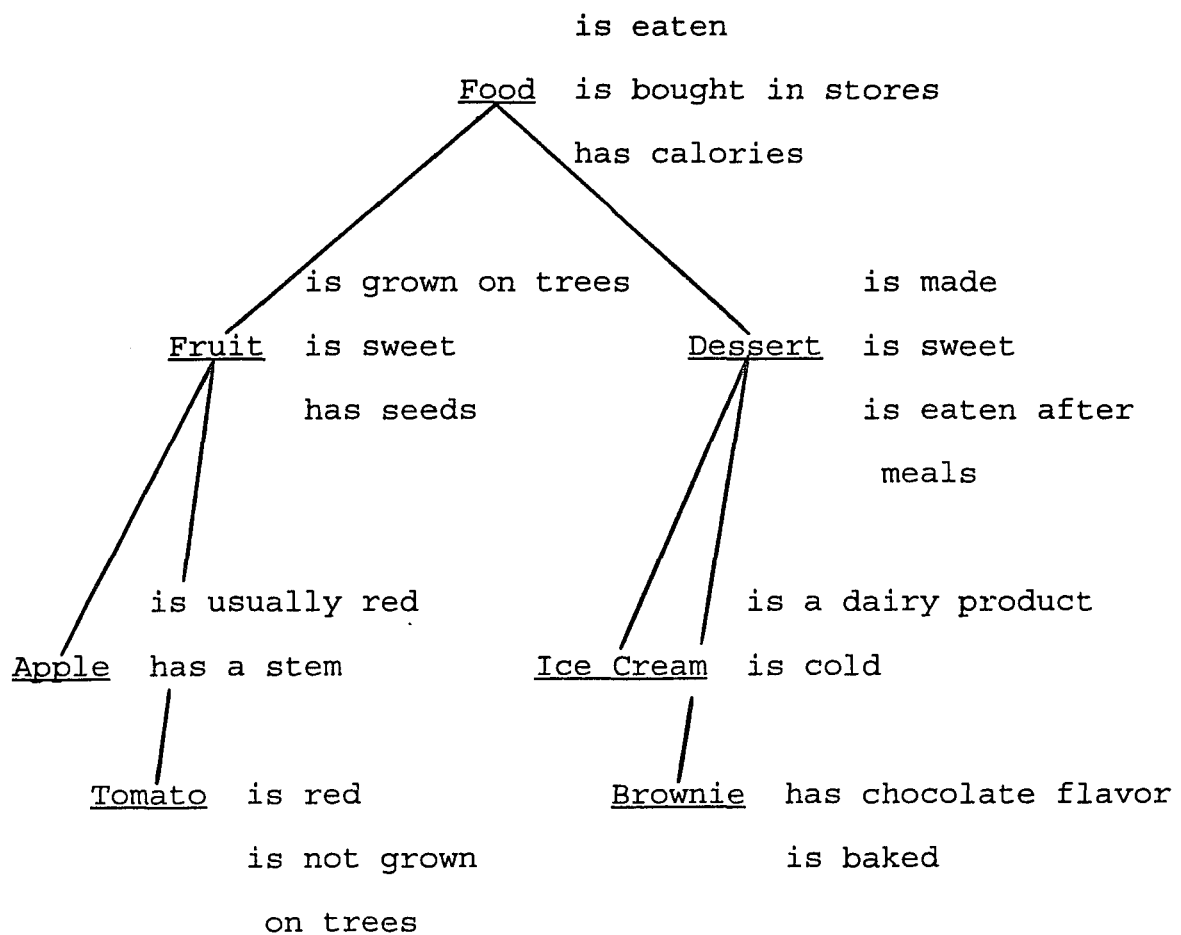


Figure 1. An illustration of the Collins and Quillian (1969) Hierarchical-Network Model.

The model assumes that when a concept is activated by a language input, a "spread of activation" radiates from the activated node to the nodes linked to the initial node and then onto all the nodes linked to the secondary nodes, etc. In this way, concepts which are related to the initially activated concept are primed by the spread of activation;

unrelated concepts do not receive any activation and so remain unprimed.

Spreading-Activation Model In 1975, Collins and Loftus elaborated on the Collins and Quillian model to account for additional experimental results. The organization of this model is based upon semantic similarity (see Figure 2) and as a result, is less hierarchical than the 1969 model. Nodes which are related are directly connected (e.g., apple and food could be directly connected). In addition, property nodes can be connected to concepts from different categories. In this model, the spread of activation proceeds along a decreasing gradient such that the nodes which are further away from the source receive less activation than nodes which are closer to the source. The source node continues to release activation for as long as it is processed, but once processing stops, the spread of activation stops and the activation in the system slowly decays over time.

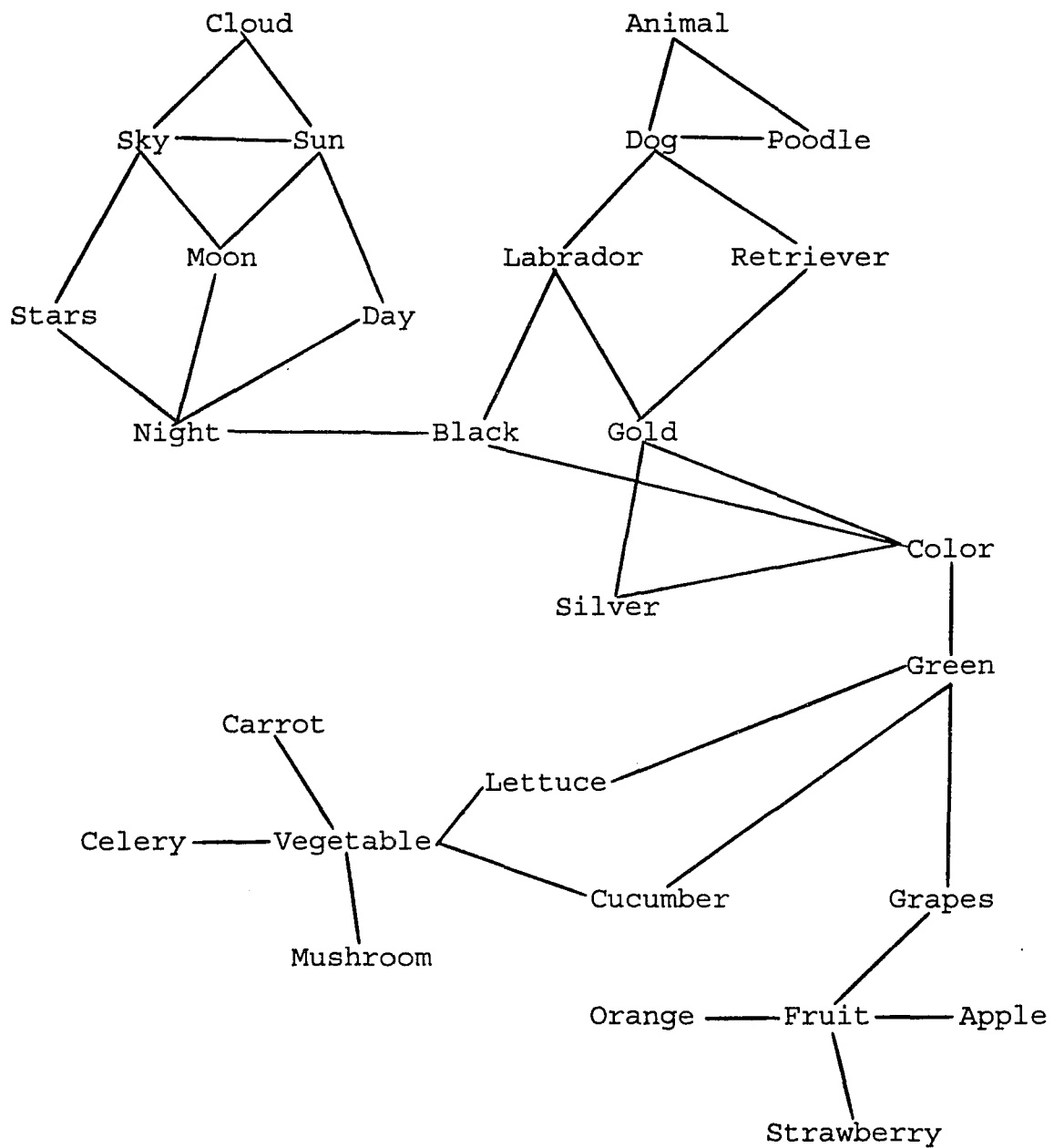


Figure 2. A schematic representation of the Collins and Loftus (1975) Spreading-Activation Model.

A2. Feature Models

In feature models, concepts (e.g., birds, or robins) are represented as lists of distinctive attributes (e.g., feathers, fly, beaks). Membership of a particular object (e.g., robin) in a particular class is computed through list comparisons (Chang, 1986; McCloskey and Glucksberg, 1979). For example, the greater the number of common attributes in two lists, the stronger the putative relation; the fewer (e.g., penguin), the more problematic the relation. Two classic feature models will be discussed here: the Smith, Shoben and Rips (1974) Feature Comparison Model, and the McCloskey and Glucksberg (1979) Property Comparison Model.

Feature Comparison Model (Smith, Shoben and Rips, 1974). In the Feature Comparison Model, the meaning of a noun concept is represented by a set a semantic features (e.g., size, color, material made of) and ranges of acceptable values for those features. These features are ranked along a continuum between essential aspects of a word's meaning and characteristic aspects and are weighted according to that ranking with the defining, or essential, features carrying the largest weights (see Figure 3). It is important to note that as a concept becomes more abstract, the number of defining features decreases.

	<u>Bird</u>	<u>Robin</u>	<u>Penguin</u>
Defining	alive	alive	alive
	breathes	breathes	breathes
	eats	eats	eats
	moves	moves	moves
	wings	wings	wings
	feathers	feathers	feathers
	beaks	beaks	beaks

Characteristic	flies	flies	swims
	sings	sings	
	many possible colors	blue	black and white

Figure 3. An example of concepts in the Smith, Shoben and Rips (1974) Feature Comparison Model.

The model postulates a two-stage process for making decisions about category membership. In the first stage, the features (both defining and characteristic) for the category and possible exemplar nouns are retrieved and compared yielding a measure of overall similarity. If that measure is greater than a positive criterion or less than a negative criterion, then a response about the relationship is made. However, if the value falls between the criteria, the second processing stage must be entered. In this stage,

only the defining features are compared. A positive response can be made if each of the defining features of a category also define the instance and if the values (or dimensions) of the instance's features fall within the range of acceptable dimensions defined by the category features.

Property Comparison Model (McCloskey and Glucksberg, 1979). This model is very similar to the Smith et al. model, except that in this model, each property is represented by a range of typical values for that property (e.g., height - 5 feet to 6 1/2 feet, could represent the range of typical values for the "height" property of the concept "man"), as opposed to a range of possible values. The properties only represent the typical members of the group and as a result should be thought of as characteristic, not defining. In order to verify category membership, the properties of the category and the possible exemplar nouns are compared until enough evidence is gathered to exceed a positive or negative criterion. In addition, these criteria are sensitive to changing expectations based on list context.

Miller and Johnson-Laird (1976) created a model which combines both network and feature characteristics. In their model, concepts are organized hierarchically into "semantic fields". Concepts are not connected in the semantic field

the way they are in network models, but they are "cross-referenced" hierarchically upwards using semantic markers (e.g., each concept includes a list of its superordinate concepts). These semantic fields are organized around conceptual cores which "are essentially common sense theories about the way the world works" (p. 300). They are abstract ideas which include knowledge of and beliefs about the objects which words denote. The structure of the conceptual core may vary from one concept to another. For example, Miller and Johnson-Laird suggest that the best conceptual core for the human body may be an image, for a social notion such as possession it may be a procedure, and for furniture it may be a list of characteristics. These abstract ideas which organize the conceptual cores have been called "prototheories"¹.

A major limitation of all of these models, as mentioned above, is that they do not provide mechanisms which explain the integration of new semantic information or changes in the existing semantic organization (Ornstein & Corsale, 1979). For example, they are unable to explain the

¹ These prototheories are reminiscent of Lakoff's (1987) theory. Lakoff hypothesized that at the most basic level, knowledge is organized using image schematic models, such as the container schema (i.e., X is either in or not in A). For example, marriage is often described in container schema language, we speak of being trapped in a marriage and sometimes recommend that people get out of marriage.

developmental shift in responding seen in word association paradigms. This change in responding has been called the syntagmatic/paradigmatic shift.

B. The Syntagmatic/Paradigmatic Shift - Word-Association Data

A word-association paradigm is an experimental procedure in which a single word is presented to a subject, who is asked to respond with the first word that comes to mind. Word associations are thought to reflect the organization of semantic memory (de Groot, 1989). Stimuli activate the semantic network and the subject's response reflects what is closely associated with the initial stimulus in the subject's semantic memory. Responses in free word-association tasks are generally characterized in one of two ways: 1) as paradigmatic, referring to responses which are from the same grammatical class and category as the stimulus word (e.g., "dog" - "cat"; "child" - "baby"; "fruit" - "apple") (also called categorical or taxonomic), and 2) as syntagmatic, referring to responses which are frequently found in syntactic sequence with the stimulus word or are from different grammatical classes (e.g., "dog" - "bark", or "child" - "cry").² There is, however, one

² De Saussure (1959) introduced the distinction between paradigmatic (termed "associative" by de Saussure) and syntagmatic processes in his structural linguistics system.

type of response that is not well characterized by these definitions. Thematic associations between nouns (e.g., cup and milk; coat and hanger; dog and bone), are related because they co-occur in event sequences (e.g., the coat was put on the hanger, the bone was given to the dog). By definition, since both words are nouns, they would be defined as paradigmatic. However, this type of association is not categorical, but more spatial, and would be better grouped with the syntagmatic associations (Lucariello, Kyratzis, and Nelson, 1992). Fortunately, thematic associates form a relatively small percentage of responses for both children and adults so this "confound" will not greatly impact our analysis of the existing word-association data.

The majority of adult responses to free word-association stimuli are paradigmatic (e.g., "dog" - "cat"), whereas children's are syntagmatic (e.g., "dog" - "bark"). This shift in response type, called the syntagmatic/paradigmatic shift, appears to occur gradually between 5 and

He argues that:

In a language-state everything is based on relations...In discourse, on the one hand, words acquire relations based on the linear nature of language because they are chained together...Combinations supported by linearity are syntagms...Outside discourse, on the other hand, words acquire relations of a different kind. Those that have something in common are associated in the memory...They are associative relations. (pp. 122-123).

9 years of age (Brown and Berko, 1960; Palermo, 1971). The shift is seen for all parts of speech examined, but appears less dramatic for nouns (Entwisle, 1966; see Table 1). One explanation for this, is that the noun shift begins before 5 and has not been measured. The gradual shifts in the other parts of speech appear to begin around 5.

Table 1. Percentage of paradigmatic responses in a word-association task@. (Adapted from Word Associations of Young Children, by D. R. Entwisle, 1966, p. 59. Copyright 1966 by The Johns Hopkins Press. Reprinted by permission).

	Kinder- garten	First grade	Third grade	Fifth grade	College
Nouns	61.2	62.7	72.9	78.1	77.1
Adjectives	16.8	31.7	70.6	78.5	65.8
Verbs	16.6	20.4	47.5	59.6	60.0
Adverbs	8.6	17.9	51.2	62.1	78.9
Pronouns	16.5	29.8	65.4	65.2	78.0

@ Responses per entry are: 1,600 for kindergarten, fifth grade and college samples; 2,240 for first and third grade samples.

The syntagmatic/paradigmatic shift has been extensively studied (for a review see Nelson, 1977) and there are a few

other response patterns which are important to note. First, the commonality or the probability of the most popular responses increases with age (Lippman, 1971; Entwisle, 1966; Palermo, 1971), possibly indicating that semantic networks are more individualized in children. However, this effect is probably confounded with reliability (i.e., the likelihood of giving the same response when tested multiple times probably increases with age). Second, in adults, vocabulary level (as measured with the vocabulary subtest of the Wechsler Adult Intelligence Scale) is correlated with percent of paradigmatic responding (Lovelace & Colley, 1982) and in both children and adults, schooling has been associated with a higher proportion of paradigmatic responses (Sharp & Cole, 1972; Luria, 1976). Both of these findings suggest that education plays some role in the shift. Finally, training has been shown to increase (although just slightly) paradigmatic responding to verbs and adjectives in children (Routh & Tweney, 1972) and instruction set has been shown to increase syntagmatic responding in adults (Howard, 1979), both reflecting flexibility in responding and some control over responses.

Over the years a number of theories have been proposed to explain the word-association data and to account for the syntagmatic/paradigmatic shift. These theories range from postulating radical changes in the underlying semantic

organization (Francis, 1972; Brown and Berko, 1960) to postulating changes in the strategic approach to the task and no change in semantic structure (Entwisle, 1966; Denney, 1974). In addition, a number of theories have argued a more moderate position. They postulate that newly acquired concepts and associations are added to the existing semantic system causing some organizational changes (Ervin, 1961; Palermo, 1971; McNeill, 1966).

Entwisle (1966) presented a strategy-based hypothesis. She argued that there is a "primitive noun response" or an early bias to give noun responses to all words and as a result, the predominance of syntagmatic responses would be an artifact (e.g, if a child was given the words "ball", "run" and "red" in a word-association paradigm and responded to all of them with nouns, the child's responses would be 33% paradigmatic and 66% syntagmatic). However, many of children's syntagmatic responses are not verb or adjective/noun (e.g., "bark" - "dog", "soft" - "pillow") as would be predicted by this theory, but noun/verb or adjective (e.g., "dog" - "bark", "pillow" - "soft").

Proponents of strategy-based hypotheses have gained support from two of the response patterns discussed above. First, they have gained support from the finding that education significantly influences the timing of the shift

and that uneducated adults often respond similarly to children. This implies that the shift is affected by education. However, it is unclear whether education results in strategic or organizational changes in the semantic network. The second response pattern, the finding that training can affect children's and adult's responses, does suggest that strategies can influence responses but does not seem to explain the shift.

Alternatively, there could be some change in the semantic organization, either due to a complete reorganization or due to the acquisition of new semantic information. For example, Francis (1972) postulates that during development there is a "lengthy reorganization of the mental filing system of the preschool child based on the abilities to isolate words from sentences and to make comparisons across related constituents" (p. 956). Similarly, Brown and Berko (1960) hypothesize that the "change in word associations is a consequence of the child's gradual organization of his vocabulary into the syntactic classes called parts of speech" (p. 13).

Other theorists have argued for the expansion of the semantic network, both through the acquisition of new concepts and new features of existing concepts, and through the development of new associations between concepts.

McNeill's (1966) and Ervin's (1961) models are two examples. McNeill (1966) postulates that linguistic structure, particularly a transformational, generative grammar, is reflected in the word-association responses. He assumes that each item in memory can be specified by physical and syntactic features and that adults respond to word-association tasks with words which share multiple features with the stimulus word. Children have not acquired all of the features, particularly the syntactic features, and as a result, there are multiple words in their semantic networks which share one or two features with the stimulus word. This makes their responses less constrained and thus potentially less reliable (for similar theories also see Clark, 1970). Nelson (1977) disagrees with this theory, pointing out that it characterizes young speakers as less knowledgeable of semantics than is indicated by their use of words in connected speech. The results of Smiley and Brown (1979) support Nelson's view. They found that although first-grade children do not choose categorical associates in a forced-choice paradigm, they can explain how categorical pairs are related.

Ervin (1961) argues that associations between words develop. She hypothesizes that syntagmatic-response probabilities in children are due to the frequency with which two words are paired in language (also see Palermo,

1971). As children's experience with language increases, they begin to associate words which occur in the same sentence contexts (e.g., if the child heard "do you want to pet the cat?" and "do you want to pet the dog?", "cat" and "dog" could become associated). The mechanism responsible for this association, according to Ervin, is the child's anticipated completion of sentences and phrases (e.g., when the child hears "do you want to pet the ...", they might expect to hear "cat" but instead hear "dog", and then "cat" and "dog" develop an association). However, according to Nelson (1977), the frequency of word-association pairs does not correlate highly with their frequency of occurrence in linguistic contexts, as would be predicted by Ervin.

The semantic structure approaches have gained some support from two convergent sources. A syntagmatic/paradigmatic shift has been found using two other paradigms which are also thought to reflect the underlying semantic organization. A dichotic listening study found that young children (6 to 7 years) were better at the immediate identification of dichotically presented syntagmatic pairs and that slightly older children (9 to 10 years) were better at the identification of paradigmatic pairs (Weingarten & Anisfeld, 1981). Secondly, Anderson and Beh (1968) used an old/new paradigm in which the subject is presented with a word and must decide if she saw the word earlier in the

list. They found that first graders made more false alarm errors on distractors which were syntagmatically related to target words and that second graders and adults made more false alarm errors on paradigmatically related distractors (also see Heidenheimer, 1978).

It appears that some change in the underlying semantic structure must be postulated to account for the syntagmatic/paradigmatic shift and related data. The question of whether this is a radical reorganization or a developmental expansion, remains. One of the ways to address this question is to examine the semantic structure of adults. Do adults retain the child-like syntagmatic associations or are they lost? If they retain them, postulating a radical reorganization is not necessary. In addition, if adults do have both types of associations, are the syntagmatic and paradigmatic processes separable and what is the developmental relationship between these processes? Nelson (1977, 1985, 1986) has proposed a developmental model of semantic memory which incorporates syntagmatic and paradigmatic processes and postulates developmental layering of associations.

C. Nelson's Developmental Model of Semantic Memory

Nelson's (1991, 1986, 1985) model emphasizes the importance of day-to-day experiences in the child's development of concepts and language. This is in contrast to other models which consider the knowledge of objects and object categories as basic. Her model proposes that as infants and children participate in routine activities or events (e.g., eating lunch), they begin to build up non-linguistic schemas or "event representations" for what occurs within an activity (e.g., mommy puts me in the high chair, gives me a sandwich and drink, gives me dessert, washes my hands and face, and takes me out of the high chair) (also see Figure 4). The event representation consists of an organized structure which often has fixed temporal, spatial or causal relationships, and components (e.g., actors, actions, props, locations).³

³ Nelson's event representation theory is an developmental elaboration of Shank and Abelson's (1977a, 1977b) script model. They define a script as: a structure that describes appropriate sequences of events in a particular context. A script is made up of slots and requirements about what can fill those slots. The structure is an interconnected whole, and what is in one slot affects what can be in another. ...a script is a predetermined, stereotyped sequence of actions that defines a well-known situation (p. 422).

Act 1 - Take off clothes	mother takes off child's shoes and socks mother takes off child's shirt mother takes off child's pants and diaper
Act 2 - Play in the tub	mother lifts child into tub child plays with water toys, splashes, etc..
Act 3 - Wash	mother helps child wash their arms and legs mother washes child's hair mother rinses child's hair
Act 4 - Dry	mother lifts child out of tub mother wraps child in towel and dries child's body and hair

Figure 4. An example of a general Event Representation
(Nelson, 1985) for taking a bath.

The young child's event representation is initially holistic and is only slowly partitioned. The organization of partitioned scripts is syntagmatic or thematic in nature, because it "is based on relations between unlike elements in sequential configuration" (Nelson & Hudson, 1984; p. 149). Once a specific script or event is analyzed into components, the child can begin to notice that the components vary from day to day (e.g., lunch may consist of a peanut butter and jelly sandwich, a hamburger or spaghetti). The components in a script become represented as slots which may be filled from an experientially built up list of alternatives. Slot fillers can have different probability values for occurrence and specific slot fillers can constrain the range of possibilities for filling other slots.

The items which are slot fillers for a particular slot in a particular event representation become organized in a primitive type of category based on their functional similarity within that particular event. These slot-filler categories can be labeled by superordinate terms, if those terms have been part of the event (e.g., a parent can talk about getting dressed and putting on "clothes" and in the same context talk about specific items of clothing, such as pants, shirts, etc.). Slot-fillers are organized paradigmatically. Their organization "is based on relations between elements that can occupy the same position in a

syntagmatic structure" (Nelson & Hudson, 1984; p. 149) (also see Mandler, 1979; Mandler, Fivush, & Reznick, 1987; Richards & Goldfarb, 1986; Kleiman, 1980; Bruner, 1986; for other models which incorporate sequential and categorical organizations).

As mentioned above, these event representations are experientially based. When an activity is experienced, the memory system will try to fit it into an existing representation. If the event contains new variables, they are added to the appropriate set of slot filler alternatives. If the event is novel, a new representation is constructed. This new event representation will be built up if similar episodes occur, if not the memory for this event may gradually fade. Vitally important or unique episodes may be remembered even if they only occur once. Our memory for specific, personal experiences is called episodic or autobiographical.

Development continues as connections are made between similar objects in different event representations and between objects which serve the same functional roles in different events. These associations become less event-bound. Taxonomic categories (i.e., conventional adult categories) develop later and are dependent upon linguistic

classification which can occur at home and is usually highly emphasized in school.⁴

Nelson's theory makes very specific predictions about children's early associations and categorical structures. The earliest associations should be event specific syntagmatic associations. These should be followed by early categories which should reflect slot-filler alternatives from specific event representations (e.g., event specific paradigmatic associations).

The progression from syntagmatic to paradigmatic responding in the word-association studies discussed above, supports Nelson's model. In addition, the finding of greater variability in children's responses to a specific stimulus (i.e., the lack of commonality in responding), is consistent with the proposal that children's responses are based on personal, probably somewhat idiosyncratic, event representations. A word-association study specifically designed to examine this response progression, found that 4 year old children gave predominantly event-based, schematic responses based on function (e.g., responding "eat" to ice cream) (see Table 2) and that 7 year old children gave mainly slot-filler category responses (e.g., responding

⁴ Vygotsky (1986\1934) also stressed the importance of schooling and "initial verbal definition" (p. 148) for the development of scientific, or taxonomic concepts.

"tiger" to zebra; a non-zoo animal such as "dog" would be considered a taxonomic association⁵) (Lucariello, Kyratzis, and Nelson, 1992; also see Sell, 1992; Petrey, 1977).

Table 2. Mean number of responses (out of 27) on a word-association task by category by age. (Adapted from *Taxonomic knowledge: What kind and when?*, by J. Lucariello, A. Kyratzis, and K. Nelson, 1992, *Child Development*, 63, p. 990. Copyright 1992 by the Society for Research in Child Development, Inc.. Reprinted by permission).

<u>Response Category</u>	<u>4 Years</u>	<u>7 Years</u>
Categorical:		
Slot-filler	3.90	8.75 *
Taxonomic	.30	1.80 *
Thematic/schematic:		
<u>Function</u>	<u>8.65</u>	<u>1.55 *</u>

* $p < .05$

Other experimental research has also supported this progression. McCauley, Weil and Sperber (1976) examined semantic priming in children using picture naming latency, and found that 5-year-old children's latencies were decreased when the target picture was preceded by an

⁵ It should be noted that slot-filler responses are also taxonomically related to the stimulus word.

associated but noncategorically related picture (e.g., dog - bone), but not when it was preceded by a less associated picture from the same conceptual category (e.g., dog - lion). For older children, however, priming effects were found for both associated and categorical pictures. Forced choice matching paradigms have also shown similar results. Smiley and Brown (1979) presented children and adults with a standard picture (e.g., a picture of a bird), followed by two test pictures (e.g., a picture of a nest and a picture of a robin) and asked the subjects to choose which of the test items "goes best with the - (standard picture)" (p. 253). The preschool and first-grade children chose more thematically related pictures and the fifth graders and adults chose more categorically related pictures.

Sell (1992, also see Lucariello, Kyratzis & Nelson, 1992) extended this work to show the progression from event-based to slot-filler to taxonomic organization. She presented preschool, kindergarten and fourth-grade children with a picture matching task in which the child was given a target picture (e.g., cheese) and asked which of three other pictures (e.g., event-based choice - knife, slot-filler choice - lunch meat, taxonomic choice - carrot) went best with the target. Particularly important for the present discussion, is her analysis of the children's explanations for their picture choices and for the pictures they did not

select. She found that preschoolers could give event-based explanations for event-based picture pairs but could rarely explain slot-filler or taxonomic pairs. Kindergartners could explain event-based and slot-filler pairs but not taxonomic pairs. However, they gave some taxonomic explanations for the slot-filler pairs suggesting that taxonomic categories were emerging. Fourth graders could explain all picture pair types. This progression has also been illustrated using category production tasks (Lucariello, Kyratzis, & Nelson, 1992) and list recall (Lucariello & Nelson, 1985).

Nelson argues that syntagmatic and paradigmatic organizational processes are the basis of semantic acquisition and development. Assuming that she is correct and that these processes are involved in initial learning; the question remains whether these processes are also involved in the day-to-day use of information in semantic memory. Pellegrino and Ingram (1979) argue that this distinction between "organization as process and the product of a process" (p. 22) should be made. However, Van Petten and Kutas (1991) warn that "the distinction between memory and process is clearly a metaphor drawn from computer science" and "should not be applied seriously to biological systems" (p. 162). In either case, if these two processes are involved in our everyday use of semantic information,

they should be observable and distinguishable in normal adults and they should be susceptible to differential breakdown in neurologic disorders. It should be noted that even if these processes are only implicated in the acquisition of semantic structures, they should still be observable in adults acquiring new knowledge.

D. Aphasia

The distinction between syntagmatic and paradigmatic processing has been applied by Jakobson (1971) and Luria (1973) to the differential disruption of semantic memory in aphasia. They have argued that damage to posterior areas (specifically Wernicke's area) is associated with paradigmatic deficits and damage to more anterior areas (specifically Broca's area) is associated with syntagmatic deficits. The demonstration of a differential breakdown of these processes would lend support to their existence and their separability in adults.

Wernicke's area is the area adjacent and posterior to the primary auditory cortex of the dominant cerebral hemisphere (Zurif, 1980). As mentioned above, damage to this area has been thought to cause deficits in categorical or paradigmatic language processes (Luria, 1973; Caramazza and Berndt, 1978). A clinical description of these patients

include: 1) the omission of the agent or subject of a sentence, 2) the frequent omission of other nouns, as well as verbs, adjectives and adverbs, 3) the use of nonspecific nouns (e.g., thing) and verbs (e.g., do), and 4) the presence of verbal and literal paraphasias and neologisms (Jakobson, 1971; Benson, 1985; Tartter, 1986; Geschwind, 1970; Goodglass and Geschwind, 1976). All of these suggest that Wernicke's aphasics have difficulties accessing specific semantic terms. However, these patients have fluent, relatively syntactically intact speech, suggesting to Luria that the syntagmatic processes (e.g., the sequential associations between words) are unimpaired (e.g., "Well, this is ... mother is away here working out o'here to get her better, but when she's looking, the two boys looking in the other part. One their small tile into her time here. She's working another time because she's getting, too ..."; Goodglass & Geschwind, 1976; p. 410).

With damage to the lower portion of the frontal lobe, particularly the inferior left frontal gyrus and the surrounding fields, in the dominant cerebral hemisphere (Broca's area, Zurif, 1980), there are deficits in the syntagmatic processes of language, or the "ordering of linguistic components in time and space" (Damasio, 1992; p. 534). This deficit has also been described as a disorder of the sequential or syntactic organization of language

(Caramazza and Berndt, 1978). A clinical description of the impairments in these patients include: 1) nonfluent speech, 2) the omission of conjunctions, prepositions, pronouns, articles and word endings, 3) the substitution of a second noun for the verb (e.g., instead of "the house is burning" they might say "house ... and ... fire..."; Luria, 1973, p. 63), and 4) the use of verbs which are unmarked for person and tense (Jakobson, 1971; Benson, 1985; Geschwind, 1970; Tartter, 1986). The speech of these patient has been referred to as telegraphic due to the omission of functors and agrammatic due to the apparent loss of syntactical rules (Jakobson, 1971). However, their language is generally meaningful (e.g., "Yes...ah...Monday...ah...Dad and Peter Hogan (patient's name), and Dad...ah...Hospital...and ah ...Wednesday... Wednesday, nine o'clock and ah Thursday... ten o'clock ah doctors...two...two...an doctors and...ah... teeth...Yah. And a doctor...and girl...and gums, and I."; Goodglass, 1973; p.185).

Before going further, the distinction between syntagmatic association and syntax must be discussed. Syntagmatic and paradigmatic, as they are used here, refer to organizational structures and processes which allow for the representation of semantic material. A deficit in syntax, for example an inability to understand passive sentences, does not necessitate semantic disorganization.

Many of the theories of transformational grammars assume that the underlying semantic structure of passive sentences is their active form and that a "transformational" rule is responsible for the different surface structure (Chomsky, 1965). So the inability to understand passives when the active forms are comprehensible, suggests difficulty with the transformational rules, not with the understanding of semantic sequences. Some syntactic errors, however, do reflect deficits in the sequencing of semantic units in the deep structure and would be considered syntagmatic (e.g., misunderstanding reversible sentences, such as "the man hit the girl").

Despite the clinical characteristics of Wernicke's and Broca's aphasics, which do suggest differential underlying deficits in paradigmatic and syntagmatic processes, the experimental data from a variety of paradigms is somewhat inconclusive. Blumstein and Milberg (Blumstein, Milberg and Shrier, 1982; Milberg and Blumstein, 1981), and Katz (1988) have found semantic priming for categorical pairs in normal controls, Wernicke's and anterior (mixed Broca's and transcortical) patients in auditory lexical decision tasks. In a visual lexical decision task, significant priming was found for Wernicke's patients and normals. For anterior patients (5 Broca's and 1 conduction), priming was in the correct direction but was not statistically significant. It

should be noted that Wernicke's patients generally responded more slowly and made more errors than the other two groups. Anterior patients responded more slowly and made slightly more errors than normals. These results have been used to argue that anterior and Wernicke's patients have intact semantic networks (Blumstein, 1988). However, the categorical stimuli in these studies were highly typical category members.

A number of studies have found that posterior patients have difficulties with atypical category members. Grober, Perecman, Kellar, and Brown (1980) used a categorization task, in which patients were given a superordinate category name (e.g., furniture) and then asked to judge whether basic level objects (e.g., chair - typical exemplar, rug - atypical exemplar and window - related non-category member) depicted in pictures and represented by written names were members of that category. Both anterior and posterior aphasics could categorize typical category members, but posterior patients made significantly more errors when classifying atypical category members and related nonmembers. Posterior aphasics performed as if their category boundaries were not well-defined suggesting paradigmatic difficulties (also see McCleary & Hirst, 1986; Zurif, Caramazza, Myerson, & Galvin, 1974).

The experimental data thus far lend support to the hypothesis that Wernicke's aphasics have some paradigmatic deficits and that these processes are primarily intact in Broca's aphasics. Grossman and Carey (1987) examined syntagmatic and paradigmatic processes from a slightly different perspective, the acquisition of a new concept. They taught Broca's and Wernicke's aphasics a made up word ("bice" - an adjective referring to an olive green) by presenting it three times in a "naturalistic" linguistic context. Subjects were then asked to judge the correctness of sentences, some of which included the word "bice". Half of the sentences which contained the word "bice" used it as an adjective (which would be correct) and the other half used it as a verb (which would be incorrect). Subjects were also asked to classify a series of objects as "bice" or "not bice". Wernicke's aphasics were able to judge relatively accurately the correctness of the sentences; but, were unable to label objects as "bice" and "not bice" suggesting that the semantic meaning of the word had not been learned but that the sequential associations had been learned. Broca's aphasics were relatively accurate on the object classification task, although they tended to label objects as "bice" based on their color and their shape. However, they were unable to judge the correctness of the sentences, indicating they had not learned the sequential, syntagmatic associations.

It is unclear if the syntagmatic deficit seen in the Broca's patients in the above study is due to a disorder in a process involved in acquisition or a process involved in the use or activation of semantic information. Aphasics' responses to a word-association task suggest that the syntagmatic organization in both populations may be intact (Gewirth, Shindler & Hier, 1984). Broca's and Wernicke's patients and normal controls made the same proportion of syntagmatic responses. The paradigmatic responses were not as clear since Wernicke's patients made a large number of idiosyncratic (i.e., nonsensical) and identity (i.e., repeated the stimulus word) responses and Broca's patients made a large number of null (i.e., no response) and idiosyncratic responses.

A number of studies have directly examined the syntactic abilities in Broca's aphasia patients. Unfortunately, many of these studies did not have brain-damaged or normal control groups so it is extremely difficult to interpret the data. The three studies which did include Wernicke's aphasics found similar deficits for both patient groups (Caramazza & Zurif, 1976; Kolk & Friederici, 1985; Heilman & Scholes, 1976). It is of course possible that Broca's and Wernicke's patients had difficulties with the tasks for different reasons. The poor performance in the Wernicke's patients could have been due

to single word processing deficits. On a sentence/picture matching task, in which the subject is read sentences and must point to the appropriate pictures, Broca's aphasics make more errors on reversible (e.g., "The dancer applauds the clown") and improbable (e.g., "The girl that the horse is kicking is brown") sentences than on non-reversible (e.g., "The boy kicked the ball") and probable sentences (e.g., "The children applaud the clown"; Caramazza and Zurif, 1976; Schwartz, Saffran and Marin, 1980; Kolk and Friederici, 1985). Caramazza and Zurif (1976) have suggested that Broca's aphasics have difficulties with sentences which must be interpreted from the syntactic structure alone.

Deficits have also been seen on sentence production (Saffran, Schwartz and Marin, 1980) and grammatical judgement tasks (Linebarger, Schwartz and Saffran, 1983). In the first study, patients were shown pictures and asked to construct, both orally and visually (by arranging cards with noun phrases and verb phrases), sentences to describe pictures. The pictures either showed relations between two animate objects (e.g., a girl running towards a man), two inanimate objects (e.g., a pencil in a sink) or one animate and one inanimate object (e.g., a girl running towards a house or a bird in a sink). Broca's aphasics made more word-order errors in the conditions where the objects were

alike in animacy, possibly because these sentences were more reversible. In the second study, Broca's aphasics were asked to make grammatical judgments about 10 different types of auditorily presented sentences. Their performance was better than chance, but not perfect.

In general, the overall pattern suggested by the clinical descriptions was found in the experimental data; Wernicke's aphasics have particular difficulty with paradigmatic processing and Broca's aphasics have more difficulty with syntagmatic processing. It remains to be determined if Wernicke's aphasics have any syntagmatic impairments or if Broca's aphasics have subtle paradigmatic deficits.

E. Methodological Approaches

Syntagmatic and paradigmatic processing were examined in this dissertation using behavioral and electrophysiological measures collected during semantic and lexical decision tasks in both the visual and auditory modalities. Semantic decision (Shoben, 1982) is an experimental procedure in which the subject is presented with a pair of words and asked to determine if they are from the same category (e.g., "dog-cat", "dog-tree"). Lexical decision (Shoben, 1982), on the other hand, is a paradigm in

which the subject is asked if a string of letters is a word (e.g., "cat") or a nonword (e.g., "cas"). The lexical decision tasks can be modified to examine semantic organization and the resulting tasks are similar to semantic decision tasks. In these procedures, the subject is presented with two strings of letters and is asked to judge whether the second string is a word or a nonword (e.g., "dog-cat", "dog-cas"). The pairs in which the second letter string is a word, can either be related (e.g., "dog-cat") and then they are similar to the related semantic decision pairs, or they can be unrelated (e.g., "dog-tree"), which makes them similar to the unrelated semantic decision pairs.

Subjects' response accuracy in both types of tasks is generally very good, so the critical measure is how long it takes them to respond (i.e., reaction time). Relative reaction time in both tasks is considered to be a measure of the time required to activate the second word (Shoben, 1982). The two tasks differ in that the semantic decision task is considered an explicit semantic memory task since the subject is explicitly asked to judge relatedness. Lexical decision tasks are considered implicit in that subjects do not have to attend to the meaning or the relatedness of the words to perform the task.

E1. Priming

Priming, a phenomenon often examined in these paradigms, is the faster response to a target, or second, word when it follows a related word, as opposed to when it follows an unrelated word. This is thought to be the result of the spreading activation initiated by the first word "priming" related words so that they are activated more quickly if they are subsequently presented. As a result, it is thought that priming can be used to study the "structure and processing of semantic knowledge" (Shoben, 1982; p. 287).

The degree of priming is sensitive to a number of experimental manipulations. It has been argued that priming is dependent upon the stimulus onset asynchrony, or SOA (i.e., the time between the onset of the first word and the onset of the second word). Neely (1977) has used these SOA-dependent priming differences to argue for Posner and Snyder's (1975) two-process theory of attention. This theory proposes that semantic priming is the result of two types of activation: "a fast automatic inhibitionless spreading-activation process and a slow limited-capacity conscious-attention mechanism" (Neely, 1977; p. 226). However, not all studies have found differences due to SOA (Howard, Shaw, & Heisey, 1986), and studies which do show a

difference are not always in the correct direction to support this two-process model (de Groot, Thomassen, & Hudson, 1986; Becker, 1980). Other manipulations which can effect priming are instruction set and the percentage of related and unrelated stimulus pairs (den Heyer, Briand & Dannenbring, 1983). It is possible that some of the differences between studies are due to interactions of these variables (Posner, 1978).

The types of stimuli also vary from study to study. Stimuli have generally been either categorically related (as in Hines, Czerwinski, Sawyer & Dwyer, 1986; Lupker, 1984) or "associatively" related (i.e., mixed categorically and syntagmatically related; as in Howard, Shaw, & Heisey, 1986). The categorically related stimuli are generally noun/noun pairs; however, Becker (1980) also examined priming with "antonyms" which Becker says "consisted largely of adjectives" (p. 502). He found that these antonyms were responded to significantly faster than categorically related pairs but there was no difference in amount of priming. However, his stimuli were not matched for association strength or frequency. In addition, they were mixed with filler items whose relatedness and grammatical class were not specified. Howard, McAndrews and Lasaga (1981) compared "category-member" associates (i.e., paradigmatically related and all noun/noun pairs) and "descriptive-property"

associates (i.e., 2/3 syntagmatically related noun/verb and noun/adjective associates and 1/3 paradigmatically related noun/noun associates). It appears that the descriptive pairs were responded to more quickly than the categorical pairs; however, that comparison was not reported in the paper. Again there was no difference in priming. Finally, one study examined adjective-noun stimulus pairs in Serbo-Croatian and found priming for semantically related pairs (Lukatela, Carello, Kostic & Turvey, 1988). It should also be noted that syntactic priming has been shown using a lexical decision paradigm (Lukatela, Kostic, Todorovic, Carello, & Turvey, 1987). Nouns preceded by syntactically appropriate pronouns were responded to faster than syntactically incorrect pronoun-noun pairs.

Single-word lexical- and semantic-decision studies have mostly been done using visual stimuli; however, there are a few studies which have used auditory stimuli (Blumstein, Milberg, & Shrier, 1982; Katz, 1988; Radeau, 1983). All auditory studies demonstrated priming effects, but only one study (Holcomb & Neville, 1990) has directly compared auditory and visual priming. Their stimuli were mixed as to association type but the same pairs were presented auditorily and visually across subjects. They found 1) priming in both modalities, 2) larger auditory than visual priming and 3) faster responding to visual than to auditory

stimuli. It should be noted that they used a relatively long SOA (1150 msec) and that although the duration of the visual stimuli were 400 msec, the duration of the auditory stimuli varied between 270 and 700 msec.

E2. Evoked Potentials - N400

Evoked potentials were the second measure to be collected. An evoked potential is a record of the brain's electrical response to specific external stimuli. It is a temporal series of positive and negative components, some of which have been associated with different aspects of the processing of stimuli. Stimuli are presented, the brain activity is recorded, and the random or unrelated electrical brain activity (i.e., the unrelated electroencephalographic activity, or EEG) is averaged out over a number of experimental trials. Evoked potentials allow the experimenter to examine some of the real-time processes underlying language and cognition which are not always measurable using behavioral methods. The topographical, or spatial, distribution of an evoked-potential component over the scalp can also be measured to differentiate underlying processes and to begin to localize functions.

One component of the evoked potential is called the N400 signifying a negative component, occurring at about 400

msec after the presentation of the external stimuli. It appears to be associated with semantic relatedness (for a review see Kutas and Van Petten, 1988). For example, a semantically inappropriate word in a sentence such as "He spread the warm bread with socks" will produce an N400 (Kutas and Hillyard, 1980), as will a congruent but unexpected word in a sentence such as "The bill was due at the end of the hour" (Kutas and Hillyard, 1984). Further, the amplitude of the component has been found to be inversely related to semantic expectancy (Kutas & Hillyard, 1984). In addition, it appears that the size of the N400 is also partially determined by the strength of association between the expected word and the presented word, so that if "tea" is expected as the last word for the sentence, "He liked lemon and sugar with his____", the N400 for "oatmeal" would be larger than the N400 for "coffee". These effects have been shown with both visual (Kutas & Hillyard, 1980, 1984) and auditory (McCallum, Farmer & Pocock, 1984; Holcomb & Neville, 1991; Kutas, Neville & Holcomb, 1987) stimuli. The N400 component has been found to have an onset of about 250 msec, a centroparietal distribution, and a 400 msec peak (Kutas & Van Petten, 1988). In addition, it is sometimes larger and of longer duration over the right than left hemisphere (Kutas & Van Petten, 1988; Kutas & Hillyard, 1982).

There has been a controversy in the field regarding whether the N400 and a component called N2 are distinct components (Ritter, Ford, Gaillard, Harter, Kutas, Naatanen, Polich, Renault, & Rohrbaugh, 1984). N2 is a component which has been found to be sensitive to unexpected physical changes in sequences of stimuli. It generally occurs earlier in the evoked potential than the N400 but it has a similar scalp distribution and a similar response to stimulus probability (Deacon, Breton, Ritter & Vaughan, 1991). Recently, however, Connolly, Phillips, Stewart and Brake (1992) found that the two components could co-occur and were differentially affected in a masking paradigm. This result suggests that the two components are indeed distinct.

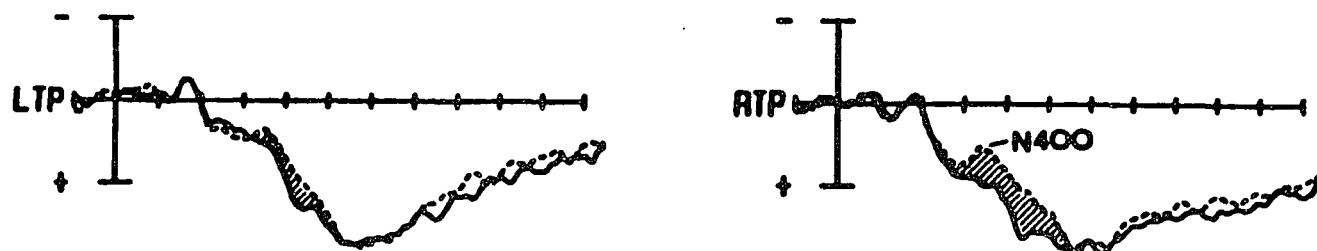
A series of studies have been done to determine if the N400 is generally sensitive to expectancy or specifically associated with semantic processing. These studies found N400s for words which were semantically unexpected but not for: 1) visual words which were larger than expected (Kutas & Hillyard, 1980), 2) auditory words which were unexpectedly spoken by a female voice, when all other words were spoken by a male (McCallum, Farmer & Pocock, 1984), or 3) for grammatical deviations (e.g., As a turtle grows its shell grew too; Kutas & Hillyard, 1983). However, N400s have been elicited by semantically anomalous picture completions to

visually presented sentences (Nigam, Hoffman, & Simons, 1992), to nameable pictures in a picture matching task (Friedman, Putnam, Ritter, Hamberger & Berman, 1992; Barrett & Rugg, 1990) and to faces in a face matching task (Barrett, Rugg, & Perrett, 1988). Although pictures and faces are not linguistic stimuli, they can be processed linguistically and are symbolic in nature. Only one study has found N400s for non-symbolic stimuli (Stuss, Sarazin, Leech & Picton, 1983; an N400 was found in a mental rotation task) and the distribution of the elicited component in this study was different from the standard, suggesting that it may be a different component. It appears that the N400 is specifically sensitive to symbolic stimuli, particularly linguistically codeable symbolic stimuli.

Recent studies have examined lexical decision using evoked potential measures (Bentin, McCarthy and Wood, 1985; Kutas and Hillyard, 1989; Holcomb, 1988; Rugg, 1985). These studies have found that the N400 is larger for unrelated words than for primed words. Holcomb and Neville (1990) presented a lexical decision task both visually and auditorily. As Figure 5 shows, there was an N400 effect in both modalities, but the amplitude was larger in the auditory than in the visual modality (this is, however, at least partially due to the later P300 for the unrelated words). This study used an SOA of 1150 msec. In general,

these studies have used long SOAs (i.e., around 1000 msec) because of the difficulties associated with the overlap of the evoked potentials elicited by the prime and the target at short SOAs. However, Boddy (1986) used SOAs of 200, 600 and 1000 msec. He found priming and larger N400 amplitudes for unrelated than related targets in all three SOA conditions. In addition, there were no differences in the amount of priming or in the size of the N400 effect between conditions. However, Boddy's results are controversial due to a subtraction procedure in the 200 SOA condition, required by the overlapping prime and target activation (Kutas and Van Petten, 1988). Boddy subtracted the evoked potential to the prime in the 1000 msec SOA condition from the evoked potential to the prime/target epoch in the 200 msec SOA condition. This subtraction requires assumptions of additivity, SOA independent responses to the target and no SOA target interaction. More recently, Besson, Fischler, Boaz, and Raney (1992) used a 300 msec SOA and found a small N400 effect (approximately 1 uV) without subtracting (it should be noted that a large number of subjects, 22, were used). As with priming, instruction set, the amount of semantic analysis required by the task (Bentin, Kutas, & Hillyard, 1993), and percentage of related pairs in the stimulus list (Holcomb, 1988; Deacon, Breton, Ritter & Vaughan, 1991), can also affect the size of the N400 effect.

(a) Visual Targets



(b) Auditory Targets



Figure 5. Holcomb and Neville's (1990) grand mean evoked potentials to related and unrelated target words for the visual (a) and auditory (b) modalities. LTP and RTP refer to electrode placements over the left and right temporo-parietal cortex. Time in msec, each tic mark is 100 msec. Stimulus onset is the vertical calibration bar. The diagonal hash lines represent the area of the N400 effect. (Adapted from Auditory and visual semantic priming in lexical decision: A comparison using event-related brain potentials, by P. J. Holcomb and H. J. Neville, 1990, Language and Cognitive Processes, 5, pp. 292-293. Copyright 1990. Reprinted by permission of Lawrence Erlbaum Associates Ltd., Hove, UK).

The interpretation of the N400 lexical decision findings is somewhat problematic given that the P300, a component associated with decision making, overlaps the N400 (see Figure 5). Kutas and Hillyard (1989) designed a task which moves the P300 out in time so that it does not overlap with the N400. In their letter probe task, the prime and target were followed by a letter and the subject had to decide whether the letter was present in either of the two words. A delay between the second word and the letter allows for the N400 processing before the subjects make their decision.

F. Rationale

Developmental studies have demonstrated changes in response behaviors in paradigms which are generally thought to reflect semantic organization in adults. Children's responses indicate that their associations are based on syntagmatic, thematically constrained, relations between objects, and their functional and physical attributes. On the other hand, adults' associations tend to be based on paradigmatic or taxonomic relations. There is a controversy in the developmental field regarding the mechanism responsible for this behavioral shift. It is hypothesized in this dissertation, that concepts and associations acquired in development are added to the child's developing

semantic network, but that the old associations are not lost. Therefore, it should be possible to demonstrate both syntagmatic and paradigmatic associations in normal adults. This dissertation used behavioral priming and N400 amplitude, two measures which have been shown to be sensitive to semantic association, to examine the organization of syntagmatically (e.g., dog-bark) and paradigmatically (e.g., dog-cat) related word pairs.

A series of methodological studies were done first, to determine the best method and optimal experimental parameters for examining this question. It was particularly important to reduce subject variability as much as possible, because a developmental follow-up is planned and children are inherently more variable.

The initial hypotheses for these studies were as follows: 1) Priming for syntagmatic pairs (e.g., noun/verb pairs) as well as paradigmatic pairs (e.g., noun/noun pairs) was predicted indicating syntagmatic and paradigmatic semantic associations. Noun/verb priming has not been demonstrated in the literature. 2) Larger priming for paradigmatic pairs than for syntagmatic pairs which are matched for association strength, was predicted, reflecting the adult bias to respond paradigmatically in word-association paradigms. 3) An N400 effect for both

paradigmatic and syntagmatic pairs was predicted, again indicating the organizational relationships. A noun/verb N400 effect has not been demonstrated in the literature.

II. METHODOLOGICAL STUDIES

These studies examined paradigmatic and syntagmatic associations of nouns. Nouns were chosen because of their prominent position in the adult models of semantic memory. Paradigmatic associates were defined as related noun/noun word pairs (e.g., dog - cat) and syntagmatic associates were defined as related noun/verb pairs (e.g., lion - roar). As discussed above, priming and N400 effects were predicted for both association types. A semantic decision paradigm was used for the first three behavioral studies to insure that subjects paid attention to the semantic meanings of the words. In the first, a long SOA was used to avoid the problem of overlapping evoked potential activity from the prime and the target in the matched evoked potential study. The second and third behavioral studies used short SOAs in an attempt to increase the priming effect. A lexical decision paradigm with a short SOA was used in the fourth behavioral study. In a fifth experiment, visual evoked potential measures were collected for a long (1100 msec) and a medium length (700 msec) SOA using the Kutas and Hillyard (1989) letter probe paradigm.

A. EXPERIMENT 1 - Long SOA Semantic Decision**A1. Method****Subjects**

Subjects were 15 undergraduate students (11 females and 4 males) at the City College of New York. They ranged in age from 20 to 35. Four of the initial 19 subjects had to be excluded because they did not make the criterion of correctly responding on 80% of the trials. All subjects were fluent in English, but many were bilingual.

Stimuli

Forty related noun/noun and 40 related noun/verb word pairs were drawn from word-association norms (Postman & Keppel, 1970). These words were then randomly reorganized (within group) to create 40 unrelated noun/noun pairs and 40 unrelated noun/verb pairs. Any resulting pairs which were judged by the experimenter to be strongly related, were again reorganized. Examples of each condition are as follows: 1) related noun/noun - author/writer, 2) related noun/verb - bed/sleep, 3) unrelated noun/noun - people/lettuce, 4) unrelated noun/verb - tobacco/roar.

The two related conditions were balanced for association strength (16.9% for the noun/noun pairs and 16.7% for the noun/verb pairs; Postman and Keppel, 1970). In order to balance for association strength, the strongest noun/noun associates (e.g., dog - cat, man - woman) could not be used. This was because the normed noun/verb associations tended to be weaker. The range of association strengths for both noun/noun and noun/verb pairs was also relatively wide because there were so few normed noun/verb pairs. In addition, some of the noun/noun stimuli were thematically related, again due to the difficulties matching the noun/noun and noun/verb stimuli on association strength. This might have somewhat reduced the difference between the noun/noun and the noun/verb priming.

The lists were matched as closely as possible for word length (5.7 letters for the first nouns in the noun/noun pairs, 4.9 for the second nouns in the noun/noun pairs, 5.1 for the nouns in the noun/verb pairs, and 4.25 for the verbs) and frequency (193 for the first nouns in the noun/noun pairs, 151 for the second nouns in the noun/noun pairs, 67 for the nouns in the noun/verb pairs and 133 for the verbs; Francis and Kucera, 1982).

The noun/noun and noun/verb word pairs were randomly ordered with the provision that no more than three word

pairs from the related and unrelated lists could occur sequentially.

The relatedness of these stimuli (in the presentation order used in the study) was then normed to insure that the stimuli were unambiguous and to verify that the noun/noun and noun/verb pairs were equivalent with respect to association strength. The stimuli were rated by 190 undergraduates in an Introductory Psychology class at the City College of New York (for their participation they received 1 point extra credit). All were fluent English speakers according to self-report. These students rated the relatedness of each stimulus pair on a scale from 1 to 7 (McCloskey & Glucksberg, 1979). The average rating for the related pairs was 6.154 (6.257 for related noun/noun pairs and 6.050 for related noun/verb pairs) with a standard deviation of .559. The average rating for the unrelated pairs was 1.590 (1.679 for the unrelated noun/noun pairs and 1.500 for the unrelated noun/verb pairs) with a standard deviation of .469. Stimulus pairs which were more than 2 standard deviations away from the respective means were discarded. This resulted in the exclusion of one related noun/noun, four related noun/verb, four unrelated noun/noun and one unrelated noun/verb pairs from further analysis. The stimuli are in Appendix A.

Procedure

Subjects were tested in one session which lasted approximately one half hour. They were seated in a comfortable chair approximately 36 inches away from a Hitachi Shibaden VM-904U black-and-white television screen. The word displays were controlled by an Apple IIc microcomputer equipped with an input/output interfacing system (Cochran, 1984). A master control program was written which presented the stimuli and collected responses and reaction times.

Subjects were presented with a total of 160 word pairs in blocks of 20. For each word pair, the subject saw two words for 100 msec, separated by a 1000 msec delay (1100 msec SOA). Subjects were instructed to respond by pressing the lever on a hand-held response box up, if they thought the words were strongly related, and down, if they thought the words were not strongly related. The subjects were given the example of "tree" and "leaf" as a strongly related pair and "tree" and "grass" as a "not strongly related" example. A distinction was made between "strongly related" and "not strongly related" word pairs because many of the noun/verb pairs could occur sequentially in a sentence, even though they were unrelated. The distinction was an attempt to minimize false positive errors. Reaction time and

accuracy were recorded for each trial. The initiation of each trial was controlled by the experimenter (the time between the trials was approximately 1 second). Twenty practice trials preceded the experimental trials.

Data Analysis

Mean error rates and mean reaction times from correct trials were calculated for each condition for each subject. Trials on which the reaction times were less than 200 msec or greater than 2000 msec were considered outliers and were excluded from the analyses. Two-way ANOVAs comparing relatedness and type of association (syntagmatic or paradigmatic) were performed on the mean reaction times and error rates.

A2. Results and Discussion

Error Data

The overall average percent correct was 90.0. A two-way ANOVA with repeated measures found a main effect of relatedness ($F(1,14)=5.89$, $p<.05$) indicating fewer errors on unrelated trials. By condition accuracy was: related noun/noun - 86.7%, related noun/verb - 89.1%, unrelated noun/noun - 94.2%, unrelated noun/verb - 93.2%.

Reaction Time Data

A two-way ANOVA with repeated measures was calculated for the reaction times from correct trials. There was a main effect indicating that verbs were responded to more quickly than nouns ($F(1,14)=6.36$, $p<.05$), but there was no significant priming effect (see Table 3). Priming as discussed in the Methodological Approaches section of the Introduction, was defined as the difference between the reaction times to the unrelated stimuli and the related stimuli.

Table 3. Experiment 1. Average reaction times and priming in msec.

	<u>Noun/Noun</u>	<u>Noun/Verb</u>
Related	794.2	769.4
Unrelated	812.8	791.5
Priming	18.6	22.1

It was thought that this lack of significant priming might be due to the moderate association strengths. As mentioned above, the most strongly related noun/noun stimuli (which are the stimuli used in most other studies) could not be matched with noun/verb stimuli so they were not used. To test this, an additional two-way ANOVA with repeated

measures was calculated on the reaction times for word pairs which were rated in the norming study to be 1/2 SD above the mean for the related pairs and 1/2 SD below the mean for the unrelated pairs. There was a trend toward a main effect which suggested noun/noun and noun/verb priming ($F(1,14)=3.29$, $p<.1$); however, for this subset, verbs were not responded to more quickly than nouns (see Table 4).

Table 4. Experiment 1. Average reaction times and priming in msec for the defined subset of stimuli.

	<u>Noun/Noun</u>	<u>Noun/Verb</u>
Related	751.0	736.5
Unrelated	790.1	777.4
Priming	39.1	40.9

The lack of a significant priming effect was unexpected given the robust priming effects reported in the literature, the large number of stimulus pairs (12 to 20 stimulus pairs are the standard in the literature), and the relatively large number of subjects. Four alternative explanations were developed to try to explain the results: 1) The SOA was too long to elicit priming in a semantic decision task. 2) It is possible that English access to the semantic network in subjects who learned a language other than English first is different and more variable than in subjects who learned

English first. 3) Semantic decision, which is used less in the literature, is not a good task for eliciting non-categorical priming. The stimulus pairs in this study vary in the ways in which they are related. The explicit nature of the semantic decision task may cause the subjects to debate their decisions as opposed to responding with their initial judgement, causing longer and more variable "yes" responses. and 4) Stimuli with lower and more variable association strengths result in less and more variable priming. Experiment 2 addressed two of these issues. A shorter SOA was used and only subjects with English as a first language were tested. All other aspects of the study were kept constant.

B. EXPERIMENT 2 - Short SOA Semantic Decision

B1. Method

Subjects

Subjects were 7 graduate and undergraduate students (6 females and 1 male) at the City College of New York. They ranged in age from 20 to 35. None of the subjects had participated in Experiment 1. For all subjects, English was the first language learned.

Stimuli

The stimuli were the same as in Experiment 1.

Procedure

The procedure was the same as in Experiment 1, except that a 250 msec SOA was used.

Data Analysis

The data analysis was the same as in Experiment 1.

B2. Results and Discussion

Error Data

The overall average percent correct was 93.4%. A two-way ANOVA with repeated measures found a main effect of association type ($F(1,6)=9.33$, $p<.05$) indicating fewer errors on noun/noun trials. By condition accuracy was as follows: related noun/noun - 93.0%, related noun/verb - 89.9%, unrelated noun/noun - 96.0%, unrelated noun/verb - 94.1%.

Reaction Time Data

A two-way ANOVA with repeated measures was calculated for the reaction times from correct trials. There was a main effect which indicated priming in both the noun/noun and noun/verb word pairs ($F(1,6)=6.11$, $p<.05$) (see Table 5).

Table 5. Experiment 2. Average reaction times and priming in msec.

	<u>Noun/Noun</u>	<u>Noun/Verb</u>
Related	644.9	624.8
Unrelated	693.0	685.6
Priming	48.1 **	60.8 **

** $p<.01$ on Tukey Post Hocs

A between subject ANOVA with repeated measures was calculated comparing the reaction times in Experiment 1 and 2. There was a main effect of experiment ($F(1,20)=9.94$, $p<.05$) indicating faster responding in Experiment 2. This difference could have been caused by the subject characteristics. First, Experiment 2 used a number of graduate students as subjects (4 out of 7), while Experiment 1 used all undergraduates. Second, all of the subjects in Experiment 2 learned English as their first language, while

some of the subjects in Experiment 1 learned English as a second language. A second ANOVA with repeated measures was calculated on the amount of priming to reduce the effects of across-subject reaction-time variability. This ANOVA found no main effect of experiment and no interactions with experiment indicating that the amount of priming at the short SOA was not statistically different from the priming at the long SOA.

The results of these two studies suggest that 1) priming does occur for noun/noun and noun/verb pairs, 2) noun/noun and noun/verb priming are approximately equal, 3) noun/verb pairs may be responded to more quickly than the noun/noun pairs (significant difference in Experiment 1 and same pattern in the current experiment), and 4) a subjects' first language might be a factor. The third and fourth experiments were run concurrently. Experiment 3 attempted to further increase priming by making the type of association more consistent within stimulus blocks. It was thought that if a larger priming effect could be elicited, small differences in the amount of paradigmatic and syntagmatic priming might be discernable.

Experiment 4 was done to compare the priming in semantic and lexical decision paradigms. In our semantic decision paradigm, the reaction times to "yes" and "no"

responses were compared. It has been argued that "yes" and "no" trials should not be directly compared because the processes underlying "yes" and "no" response decisions are different (McClelland, 1979; Ratcliff, 1978; Posner, 1978). As a result, it is possible that the amount of priming in the semantic decision paradigms was confounded by comparing "yes" and "no" trials. In lexical decision paradigms, on the other hand, the subject responds "yes" to both of the conditions of interest (i.e., the second stimuli in the related and unrelated pairs of interest are always words so the correct response is "yes").

C. EXPERIMENT 3 - Blocked, Short SOA, Semantic Decision

C1. Method

Subjects

Subjects were 8 undergraduate students (5 females and 3 males) at the City College of New York. They ranged in age from 20 to 35. None of the subjects had been in either of the previous studies. For all subjects, as in Experiment 2, English was the first language learned.

Stimuli

The stimuli were the same as in Experiment 1, except that the noun/noun and the noun/verb stimuli were presented in separate blocks. Stimulus sets were counterbalanced so that some subjects received noun/noun sets first and others received noun/verb sets first.

Procedure

The procedure was the same as in Experiment 2. The SOA was again 250 msec.

Data Analysis

The data analysis was the same as in Experiment 1.

C2. Results and Discussion

Error Data

The overall average percent correct was 93.7%. A two-way ANOVA with repeated measures found a main effect of relatedness ($F(1,7)=7.58$, $p<.05$) indicating fewer errors on unrelated trials. By condition accuracy was as follows:

related noun/noun - 93.9%, related noun/verb - 88.5%,
unrelated noun/noun - 95.1%, unrelated noun/verb - 96.8%.

Reaction Time Data

A two-way ANOVA with repeated measures was calculated for the reaction times from correct trials. There was a main effect of relatedness indicating priming in both the noun/noun and noun/verb word pairs ($F(1,7)=17.38$, $p<.05$) (see Table 6). There was no indication of priming differences in the paradigmatic and syntagmatic pairs.

Table 6. Experiment 3. Average reaction times and priming in msec.

	<u>Noun/Noun</u>	<u>Noun/Verb</u>
Related	701.9	672.9
Unrelated	798.8	767.2
Priming	96.9 *	94.3 *

* $p<.05$ on Tukey Post Hocs

A between-subject ANOVA comparing the priming from Experiments 3 and 2 found no main effect of experiment and no interaction with experiment. This indicates that the increase in priming due to blocking the stimuli was not statistically significant.

D. EXPERIMENT 4 - Short SOA Lexical Decision

This study was originally designed to compare the priming associated with semantic and lexical decisions within subjects. However, the first 7 subjects had great difficulty shifting instruction set in the within-subject paradigm and as a result, responded more slowly and made more errors. Subsequent subjects only received the lexical decision paradigm. Semantic (Experiment 2) and lexical decision were compared between subjects.

D1. Method

Subjects

Subjects were 9 undergraduate students (6 females and 3 males) at the City College of New York. They ranged in age from 20 to 35. None of the subjects had been in any of the previous studies. For all subjects, English was the first language learned. Two of the subjects received the lexical decision condition first followed by the semantic decision condition and the seven other subjects only received the lexical decision task.

Stimuli

The stimuli were the same as in Experiment 1, except that only half of the stimuli (80 pairs) were presented (the other half were to be used in the semantic decision part of this experiment). A list of 80 pronounceable nonwords was created by changing a single letter in the second word in the pairs. Each of the first words were then randomly paired with one of the nonwords. The related word pairs, the unrelated word pairs and the word/nonword pairs were then randomly reorganized with the condition that no more than three word/word or word/nonword pairs could occur in a sequence. Experiments 3 and 4 were run concurrently so the word pairs were not blocked by association type.

Procedure

The procedure was similar to that of Experiment 2, except that subjects were instructed to respond "yes" if the second word was a real English word and "no" if it was not a real English word. The SOA was again 250 msec.

Data Analysis

Only the reaction times to word/word (i.e., "yes") trials were analyzed because the primary focus of this

dissertation was an examination of the semantic organization of words. In addition, it is unclear how to interpret responses to nonword stimuli or how to compare them to responses to word stimuli. The data analysis of the word/word trials proceeded as in Experiment 1.

D2. Results and Discussion

Error Data

The overall average percent correct was 94.9%. A two-way ANOVA comparing relatedness and association type found no main effects or interaction. By condition accuracy was as follows: related noun/noun - 98.2%, related noun/verb - 95.7%, unrelated noun/noun - 96.1%, unrelated noun/verb - 94.0%, and word/nonword - 93.4%.

Reaction Time Data

A two-way ANOVA with repeated measures was calculated for the reaction times from correct, word/word trials. There was a main effect of relatedness indicating overall priming ($F(1,8)=10.05$, $p<.05$). However, Tukey Post Hocs were not significant for either association type comparison (see Table 7). Again there was no indication of priming differences in the paradigmatic and syntagmatic pairs.

Table 7. Experiment 4. Average reaction times and priming in msec.

	<u>Noun/Noun</u>	<u>Noun/Verb</u>
Related	706.2	693.4
Unrelated	742.8	735.6
Priming	36.6	42.2

A between-subject ANOVA comparing the priming for Experiments 4 and 2 found no main effect of experiment and no interactions with experiment indicating that there was no statistically significant difference between the semantic and lexical decision priming.

Experiment 5 was done to examine the N400 effects associated with paradigmatic and syntagmatic stimulus pairs. A letter probe task was used in which the subject was asked to decide if a specific letter was present in either of the stimulus words (Kutas and Hillyard, 1989). This protocol was used instead of the semantic or lexical decision tasks to separate the N400 and the P300 for easier analysis of the evoked potentials (see Methodological Approaches section). Because this study was run concurrently with Experiments 3 and 4, Experiment 5 was run with the mixed stimulus list used in Experiments 1 and 2.

E. EXPERIMENT 5 - Letter Probe Evoked Potential**E1. Method****Subjects**

Subjects were 9 undergraduate students (7 females and 2 males) at the City College of New York. None of the subjects had participated in the other four studies. Eight of the subjects were right-handed and 1 of the subjects was left-handed. They ranged in age from 19 to 45. For all subjects, English was the first language learned. Seven other subjects had to be excluded, six because their combined error rates on the semantic decision and letter probe tasks resulted in fewer than 20 evoked potential sweeps per condition (averages with fewer than 20 trials are difficult to interpret and measure because of the EEG) and one because, in the experimenter's judgement, he presented a language-impaired profile on the vocabulary, similarities and picture arrangement subtests of the WAIS-R (these subtests were administered as part of a pilot investigation).

Stimuli

The word pair stimuli and the stimulus presentation order from Experiment 1 were used.

The letter probes (Kutas and Hillyard, 1989) were determined by randomly assigning 50% of the word pairs to a "yes" condition (i.e., the response to the letter probe task would be a yes) and 50% to a "no" condition (i.e., the response to the letter probe task would be a no). The "yes" group was then further randomly divided so that for 50% of the trials the letter would be in the first word and for 50% of the trials the letter would be in the second word. Finally, a random number between 1 and 5 was assigned to each trial in the "yes" group. This number determined whether the letter probe would be the first, second, third, fourth or fifth letter in the word. Based on these random assignments, the letters for the "yes" condition of the letter probe task were chosen. The same letters which were used for the "yes" condition were also used for the "no" condition. The letters were randomly assigned to word pairs in the "no" condition with the stipulation that the letter not be present in either of the words. These manipulations resulted in 92 consonant and 68 vowel letter probes.

Procedure

Subjects were tested in one session which lasted approximately two and one half hours. Seating and stimulus presentation were the same as in Experiment 1.

Subjects were presented with the same 160 word pairs which were presented in Experiment 1. However, the subjects' task was to determine whether a letter, presented 1500 msec after the second word, was present in either of the words. This paradigm was modeled after a task designed by Kutas and Hillyard (1989). The pairs were again presented in blocks of 20 pairs. For each word pair, the subject saw the initial word for 100 msec followed by a 1000 msec delay (offset to onset) for 5 subjects and a 600 msec delay for 4 subjects. The second word was also presented for 100 msec and was followed by a 1500 msec delay. The probe letter followed by a question mark was then presented for 250 msec and, as mentioned above, the subject's task was to determine if the letter was in either word presented. The subject responded by pressing a lever up on a box if the letter was present and down if the letter was not present. Following each trial, the subject was asked to report the two words and the letter to insure that they had read the words. The initiation of each trial was controlled by the experimenter. Evoked potentials were recorded for 2100 msec

epochs (for 1100 SOA subjects) or 1000 msec epochs (for 700 SOA subjects). The 2100 msec epoch began 100 msec before the onset of the first word and the 1000 msec epoch began 100 msec before the onset of the second word. Twenty practice trials preceded the experimental trials.

Following the evoked-potential paradigm session, each subject was shown all 160 pairs again and the reaction times to decide whether or not the two words were strongly related were recorded. The procedure for this part of the experiment was identical to that of Experiment 1.

EEG Recording Procedure

Evoked potential activity was recorded using Nicolet SM 200 physiological amplifiers and a Nicolet Pathfinder II computer averaging system. The Nicolet Pathfinder II was triggered by the Apple II/E interfacing system (Cochran, 1984) and controlled by a MECOL program. Two silver/silver chloride scalp electrodes were used, each references to linked ear lobes and grounded with an electrode on the forehead. The electrodes were placed according to the International 10-20 system at Cz and either Fz or Pz. Electrode sites were abraded before application of an electrolyte-filled electrode, and inter-electrode impedances

were kept below 5 kOhms. The sampling interval was 4.2 msec.

Individual trials were collected on floppy disks. After the experiment, the evoked potentials for the word pairs which were responded to correctly on the letter probe task and the semantic decision task were binned by condition, by subject. The evoked potentials were band-passed at 1-100 Hz.

Data Analysis

The latency of the most negative point at Cz in a typical N400 window, the 300-400 msec window post onset of the target word, was identified. Mean amplitude at Cz was calculated for a 100 msec window around the average peak latency of 347 msec (300-400 msec window). Two-way ANOVAs were done on the resulting mean amplitudes and latencies.

E2. Results and Discussion

Error Data

The average percent accuracy on the letter probe task was 91.9% and on the semantic decision task was 90.2%. As mentioned above, trials which contained letter probe or

semantic decision errors were excluded from the evoked potential analyses.

Evoked Potential Data

A two-way ANOVA with repeated measures was calculated for the mean amplitude at Cz in the 300-400 msec window. There was a main effect of relatedness indicating an N400 effect in both the noun/noun and noun/verb word pairs ($F(1,8)=7.99$, $p<.05$) (see Table 8 and Figure 6).

Table 8. Experiment 5. Mean amplitudes in μV at CZ.

	<u>Noun/Noun</u>	<u>Noun/Verb</u>
Related	-.14	-.02
Unrelated	-1.46	-1.71
Difference	1.32 **	1.69 **

** $p<.01$ on Tukey Post Hocs

The N400 effect (defined as the difference between the N400 mean amplitudes for related and unrelated stimuli) appeared to be larger for the 1100 SOA than for the 700 SOA (see Table 9). This difference was not significant in a 3-way ANOVA; however, there were only 4 subjects in one group and 5 in the other.

Table 9. Experiment 5. The N400 effect in uV by SOA at Cz.

	<u>Noun/Noun</u>	<u>Noun/Verb</u>
700 SOA	.67	1.03
1100 SOA	1.84	2.22

There was also a main effect of relatedness in an ANOVA with repeated measures done on the latency of the most negative point ($F(1,8)=9.63$, $p<.05$). The latency was shorter for the related than for the unrelated stimuli (see Table 10).

Table 10. Experiment 5. Mean peak latency in msec at CZ.

	<u>Noun/Noun</u>	<u>Noun/Verb</u>
Related	344.6	331.7
Unrelated	351.6	359.7

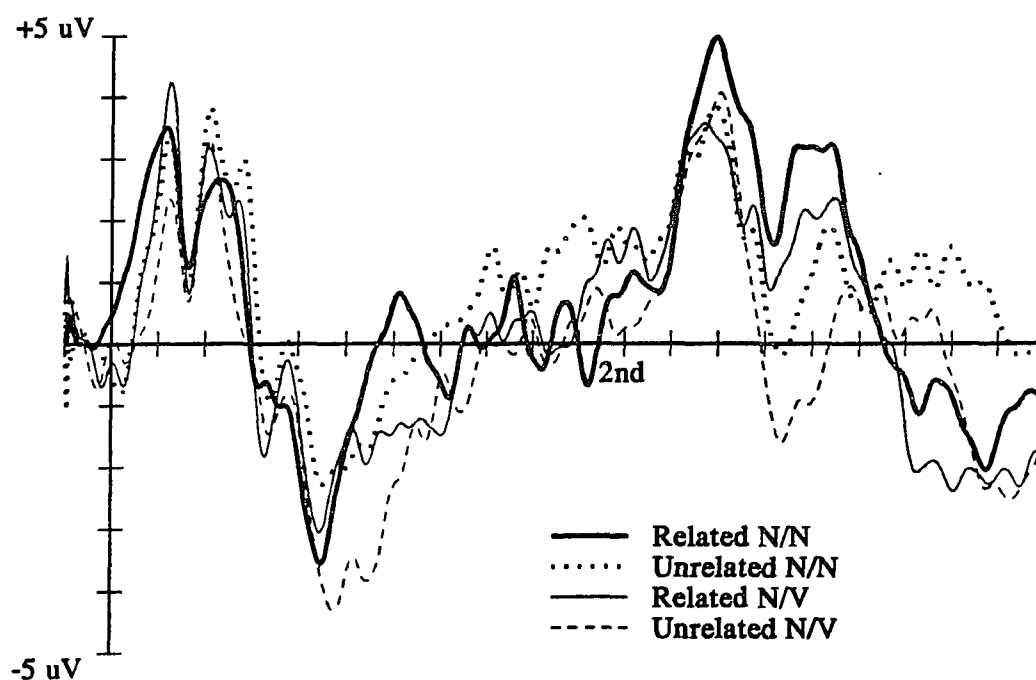


Figure 6. Experiment 5. Grand mean evoked potentials recorded at Cz for the 5 subjects with the 2100 msec epoch. This epoch began 100 msec before the presentation of the prime. Presentation of the prime is indicated by the calibration bar and presentation of the target (second word) is marked on the X axis. Each tic mark on the X axis represents 100 msec.

In summary, this study shows that N400 effects do occur for noun/noun and noun/verb stimulus pairs, and suggests that the amplitude is equal for the two types of stimulus pairs.

F. General Discussion of Methodological Studies

Five studies were conducted to 1) test some initial hypotheses and 2) examine the relevant experimental parameters. It was predicted and established that priming and N400 effects are seen in adults for both noun/verb and noun/noun stimuli. It is important to note that this constitutes the first documentation of priming (semantic and lexical) and N400 effects in noun/verb pairs. It was further predicted that noun/noun priming would be larger than noun/verb priming, given the adult bias to respond paradigmatically in a word-association paradigm. This was not supported. All statistical analyses indicated no differences between the noun/noun and the noun/verb pairs with respect to priming. This conclusion must be reconciled with the data from the word-association, dichotic listening and old/new list paradigms, discussed in the introduction, which seemed to suggest an organizationally based paradigmatic bias in adults.

In addition, the data suggest that: 1) priming appeared to be larger for shorter SOAs, although this effect was not significant, 2) priming appeared to be larger when stimuli were blocked, although again the effect was not significant and 3) priming was statistically equal for lexical and semantic decisions. It was further noted that, whereas priming appears to get larger at shorter SOAs, the N400 effect appears to get larger at longer SOAs. This implies that the processes underlying priming and N400 effects may be different and raises questions about the nature of these underlying processes.

A number of issues regarding the task and the stimuli were also raised by these experiments. With respect to the task, there is the issue of comparing "yes" and "no" trials in the semantic decision paradigm. As discussed above, the literature argues that "yes" and "no" responses should not be directly compared. However, our study found no statistical difference in the amount of priming between semantic and lexical decision. Nonetheless, it was decided that lexical decision tasks would be used in the next set of experiments.

With respect to the stimuli, there were four issues. First, the primes or first words for the noun/noun and the noun/verb pairs were different. Perhaps the priming and

N400 effects were due to words with primary noun associations being different from words with primary verb associations. This is supported by the differences in the length (number of letters) and frequency of the noun/noun primes and the noun/verb primes (see Stimuli section, Experiment 1). To address this concern, in the next set of experiments, stimulus pairs were created which had the same first word (e.g., "dog" - "cat"; "dog" - "bark"). Second, there were no stimulus pairs with high association strengths, which perhaps accounts for the small, and sometimes nonsignificant, amounts of priming. For the next experiments, stimulus pairs with the highest available association strengths were used and conditions were not matched for association strength. An analysis of covariance was planned to examine the effects of association strength. Further, these studies were all done visually. Since one of the goals was to establish a paradigm which could be used with children, it was decided to compare auditory and visual stimuli in the next set of experiments. Finally, only noun primes and their paradigmatic and syntagmatic targets were used. It is possible that the studies did not assess general paradigmatic and syntagmatic associations, but specific noun and verb effects. To address this issue, adjective/adjective and adjective/noun stimuli were added to the stimulus set.

III. THEORETICAL STUDIES

These studies were done to examine more general syntagmatic and paradigmatic processes. Experiments 6, 8, and 9 were lexical decision studies and Experiment 7 was an N400 study.

A. EXPERIMENT 6 - Visual and Auditory Lexical Decision

This experiment was a within-subject lexical decision study which varied SOA (650 and 1150 msec), word class of prime (noun and adjective), association type (paradigmatic and syntagmatic) and presentation modality (visual and auditory). A 650 msec SOA was used, instead of the 250 SOA used previously, because the auditory stimuli were 400 msec in duration. SOA was varied to explore whether association type or word class interacted with SOA.

The hypotheses for this experiment were as follows: 1) Priming for adjective/adjective and adjective/noun pairs was predicted indicating adjective semantic associations. Adjective priming in English had not been demonstrated in the literature. 2) Priming and reaction times were predicted to be equal for the two paradigmatic pairs (noun/noun and adjective/adjective) and 3) equal for the two syntagmatic pairs (noun/verb and adjective/noun pairs) reflecting word-

class-independent organizational processes. 4) Paradigmatic pairs were predicted to have larger priming than syntagmatic pairs reflecting the adult bias to respond paradigmatically in word association paradigms. This was hypothesized despite the null result in the first set of experiments, because of the changes in the stimuli. 5) Priming was predicted to be larger for the shorter SOA given the results of the first set of experiments. and 6) Priming patterns were expected to be the same in visual and auditory modalities.

A1. Method

Subjects

The subjects were 16 adults (12 females and 4 males) who were mostly employees at the Albert Einstein College of Medicine. They ranged in age from 20 to 45. All subjects were fluent in English before kindergarten; however, 2 subjects learned English and a second language concurrently. Since the stimuli were presented both visually and auditorily, only subjects with self-reported normal hearing and 20-20 or 20-20 corrected vision, were used. One subject was excluded because he did not meet the accuracy criterion (80%).

Stimuli

A list of 208 related word pairs was constructed. The list included 52 noun/noun (e.g., dog-cat), 52 noun/verb (e.g., dog-bark), 52 adjective/adjective (e.g., soft-hard) and 52 adjective/noun (e.g., soft-pillow) pairs. The first word, or prime, was the same for the noun/noun and noun/verb pairs (as a result, when the whole set is discussed it is referred to as noun/noun/verb) and for the adjective/adjective and adjective/noun pairs (adjective/adjective/noun). A list of 208 pronounceable nonwords was created by changing a single letter in the target words (e.g., animal-agimal).

i. Non-cued Lexical Decision Pilot

In order to equate the stimuli on various attributes (Canas, 1990) and to insure that they were unambiguous (i.e., that they were not responded to as words when they were nonwords and that they were not responded to as nonwords when they were words), the 312 words and the 208 nonwords were presented in a visual and in an auditory non-cued lexical-decision task to 5 subjects. Stimuli to which 3 or more of the 5 subjects responded incorrectly or for which the average reaction times were $\pm 2SD$ from the

overall, across stimuli mean reaction time, were excluded from the primed lexical decision task.

The 5 subjects (4 females and 1 male) were all fluent in English before kindergarten and had normal hearing and 20-20 or 20-20 corrected vision. All subjects were employees at the Albert Einstein College of Medicine. The stimuli, both the primes and the targets, were randomly ordered with the provision that related stimuli were separated by at least three words. The list was then broken down into four lists of 100 items and one list of 120 items. Each subject received the lists in a different order to control for practice and fatigue effects. Since the auditory and visual lists included the same words and were being presented to the same subjects, the visual and auditory tasks were administered approximately two weeks apart to minimize memory for the words. The visual task was administered first.

The visual stimuli were constructed using the Apple Macintosh MacDraw software package. The words were created using bold, uppercase letters and Helvetica, 14-point print. They were presented in the center of the screen for 200 msec.

The auditory stimuli were computer-digitized natural speech, spoken by a female. All stimuli, primes, targets and nonwords, were recorded individually. They were then edited to 400 msec in duration primarily by removing the silence between syllables, parts of the final consonants and parts of the vowels. The words were presented at approximately 85 db SPL peak intensity. Digitization and editing were done with the Apple Macintosh Sound Edit software package. Stimuli were delivered through Ear Tone insert earphones via a Radio Shack, Realistic amplifier.

Both the visual and auditory stimuli were sequenced with the Apple Macintosh PictSnd software program and presented with a 3 second SOA.

The mean reaction time for the visual stimuli was 750 msec (67 SD) and the overall accuracy was 97% (range of 99.6% to 94.2%). None of the visual word stimuli were ambiguous (i.e., responded to incorrectly by 3 of the 5 subjects), but eight noun/noun/verb sets and six adjective/adjective/noun sets were excluded because the reaction time for one of the stimuli was greater than 2 SD above the mean. Four of the visual nonwords were ambiguous and were replaced.

The mean reaction time for the auditory stimuli was 756 msec (129 SD) and the overall accuracy was 82% (range of 86.2% to 78.8%). Thirteen of the noun/noun/verb and 13 of the adjective/adjective/noun sets had to be excluded because one of the words was ambiguous. In addition, seven of the noun/noun/verb and three of adjective/adjective/noun sets had to be excluded because the reaction time to one of the stimuli was greater than 2 SD above the mean. Nine of the auditory nonwords were ambiguous and were replaced.

ii. Cued Lexical Decision - Visual Stimuli

Forty of the remaining visual noun/noun/verb sets and 40 of the remaining visual adjective/adjective/noun sets were then used in the visual-cued lexical decision task. It should be noted that 7 of the 40 noun/noun stimuli were thematically related. Tables 11 and 12 present the stimulus characteristics.

Table 11. The characteristics of the visual noun prime stimuli and the between-group comparisons of those characteristics. The statistical comparisons were made using two-tailed t-tests. The degrees of freedom were 39, except for association strength where it was 36.

	<u>Noun/Noun</u>	<u>Noun/Verb</u>	<u>t value</u>
Association Strength+	23.2	11.6	2.87*
Frequency++	105.8	145.1	-1.05
Number of Letters	4.8	4.2	2.24*
Number of Syllables	1.5	1.1	4.23**
Reaction Time to Targets in			
<u>Non-cued Study</u>	<u>728</u>	<u>748</u>	<u>-1.37</u>

+ Palermo and Jenkins (1964); Postman and Keppel (1970); no norms were available for three of the noun/noun and noun/verb stimulus pairs.

++ Francis and Kucera (1982)

* $p < .05$, ** $p < .01$

Table 12. The characteristics of the visual adjective prime stimuli and the between-group comparisons of those characteristics. The statistical comparisons were made using two-tailed t-tests. The degrees of freedom were 39, except for association strength where it was 17.

	<u>Adj/Adj</u>	<u>Adj/Noun</u>	<u>t value</u>
Association Strength+	23.2	12.7	0.13
Frequency++	119.3	236.4	-2.55*
Number of Letters	5.0	4.9	0.38
Number of Syllables	1.4	1.5	-0.78
Reaction Time to			
Targets in			
<u>Non-cued Study</u>	<u>744</u>	<u>731</u>	<u>1.61</u>

+ Palermo and Jenkins (1964); Postman and Keppel (1970); no norms were available for 22 of the adjective/adjective and adjective/noun stimulus pairs.

++ Francis and Kucera (1982)

* $p < .05$, ** $p < .01$

Despite the significant differences in frequency, number of letters and number of syllables, the non-cued reaction times to the noun and adjective set target words did not differ suggesting that the non-cued access to the words was matched. The effect of the difference in association

strength on priming was statistically examined using a covariate analysis.

The noun/noun/verb stimuli were divided into two lists which were balanced for the five variables in Tables 11 and 12 above and for the reaction time in the non-cued task to the prime. The adjective/adjective/noun set was also divided into two lists which were similarly balanced. None of the t-tests done comparing the lists (within condition) were significant.

The related word pairs were then randomly reorganized (within list and word class) to create 40 unrelated noun/noun, noun/verb, adjective/adjective and adjective/noun word pairs. Any resulting pairs which were judged to be strongly related, were again reorganized. Each prime was also paired (again within list and word class) with two nonwords, creating 80 noun/nonword (constructed from a noun), noun/nonword (verb), adjective/nonword (adjective) and adjective/nonword (noun) pairs. These manipulations resulted in eight blocked sets of word pairs: noun/noun - list 1, noun/noun - list 2, noun/verb - list 1, noun/verb - list 2, adjective/adjective - list 1, adjective/adjective - list 2, adjective/noun - list 1 and adjective/noun - list 2. Each set contained 40 related pairs, 40 unrelated pairs and 80 word/nonword pairs. Within each set, each prime occurred

four times (related, unrelated and two word/nonword pairs), each target occurred twice (related and unrelated pairs) and each nonword occurred twice. The stimuli were blocked by word class of the prime and association type because of the results of Experiment 3. The stimulus sets are presented in Appendix B.

Within each of the eight sets, the word pairs were randomly ordered, with two provisions. First, no more than three word/word or three word/nonword pairs could occur sequentially. Second, identical and related words had to be separated by at least three trials.

The stimulus pairs were divided into list 1 and list 2 so that two different within subject SOAs, 650 msec and 1150 msec, could be used. The time between stimulus pairs was always 3 seconds.

A Latin Square design was used to counterbalance for presentation order creating four word-pair presentation orders: 1) n/n, n/v, a/a, a/n; 2) a/a, n/n, a/n, n/v; 3) n/v, a/n, n/n, a/a; and 4) a/n, a/a, n/v, n/n. Because it was important to block word class presentation, list 1 and list 2 of each type were always presented together. List

order and SOA order were balanced creating 16 different presentation sequences (see Appendix D).

iii. Cued Lexical Decision - Auditory Stimuli

The remaining 24 auditory noun/noun/verb sets and 29 adjective/adjective/noun sets were used in the auditory-cued lexical decision task. Tables 13 and 14 present the stimulus characteristics.

Table 13. The characteristics of the auditory noun prime stimuli and the between-group comparisons of those characteristics. The statistical comparisons were made using two-tailed t-tests. The degrees of freedom were 23, except for association strength where it was 21.

	<u>Noun/Noun</u>	<u>Noun/Verb</u>	<u>t value</u>
Association Strength+	26.8	12.7	2.31*
Frequency++	125.0	173.4	-0.85
Number of Letters	4.8	4.2	2.02
Number of Syllables	1.5	1.0	3.82**
Reaction Time to Targets in			
<u>Non-cued Study</u>	<u>726</u>	<u>760</u>	<u>-1.15</u>

+ Palermo and Jenkins (1964); Postman and Keppel (1970); no norms were available for two of the noun/noun and noun/verb stimulus pairs.

++ Francis and Kucera (1982)

* $p < .05$, ** $p < .01$

Table 14. The characteristics of the auditory adjective prime stimuli and the between-group comparisons of those characteristics. The statistical comparisons were made using two-tailed t-tests. The degrees of freedom were 28, except for association strength where it was 15.

	<u>Adj/Adj</u>	<u>Adj/Noun</u>	<u>t value</u>
Association Strength+	21.6	13.7	1.20
Frequency++	125.2	253.2	-2.31*
Number of Letters	5.2	4.9	0.90
Number of Syllables	1.4	1.5	-0.53
Reaction Time to Targets in			
<u>Non-cued Study</u>	<u>760</u>	<u>724</u>	<u>1.46</u>

+ Palermo and Jenkins (1964); Postman and Keppel (1970); no norms were available for 13 of the adjective/adjective and adjective/noun stimulus pairs.

++ Francis and Kucera (1982)

* $p < .05$, ** $p < .01$

Again, there was no difference in the non-cued reaction times to the noun and adjective set targets, indicating that the non-cued access to the words was matched.

As with the visual stimuli, the related word pairs were randomly reorganized (within word class) to create unrelated

noun/noun, noun/verb, adjective/adjective and adjective/noun word pairs. Each prime was also paired (again within word class) with two nonwords, creating noun/nonword (noun), noun/nonword (verb), adjective/nonword (adjective) and adjective/nonword (noun) pairs. These manipulations resulted in four blocked sets of word pairs: noun/noun, noun/verb, adjective/adjective, and adjective/noun. The stimulus sets are presented in Appendix C.

Within each set, the word pairs were randomly ordered in the same manner as the visual stimuli. All stimulus pairs were presented with a 650 msec SOA. The time between stimulus pairs was again 3 seconds.

The visual trials were always presented first because of the greater confidence in the visual stimuli. At the beginning of the study we were unsure whether the auditory stimuli would elicit priming. Four presentation orders were used: 1) n/n, n/v, a/a, a/n; 2) n/v, n/n, a/n, a/a; 3) a/a, a/n, n/n, n/v; 4) a/n, a/a, n/v, n/n. Each order occurred once with each of the visual word class orders determined by the Latin Square design (see Appendix D).

Procedure

Subjects were tested in one session which lasted approximately 2 hours. They were seated at a comfortable distance from the computer screen (approximately 18 inches), with the index finger of their dominant hand on the reaction time key. They were read the following instructions:

You will be presented with a single word, such as "pepper", centered in the middle of the screen, followed by a blank screen and a second word, such as "pan", or a string of letters, such as "paj". Your task is to read the first word and the second string of letters and to decide if the second string is a real English word. If it is a real English word, please lift your finger (dominant, index) off of the hole. If it is not, please do not move your finger. When you put your finger back, please be careful to completely cover the hole. The mechanism under the hole is extremely sensitive to light and if your finger is not completely covering it, it will respond as if you have lifted your finger. Your primary task is to make a decision about the second string of letters, but I would also like you to read the first word. The object of this study is to see

how quickly and accurately you can determine whether the second string of letters is a real English word. You will have some practice trials before we begin the actual experiment. Do you have any questions?

The subjects were presented with the practice trials and then the experimental trials. There was a 1 to 2 minute break between lists and a 5 to 7 minute break half way through the visual trials. Subjects were again given a 5 to 7 minute break after the visual trials and then the instructions for the auditory task were read:

This second part is exactly the same as the first part, except that the words will be spoken instead of written. Listen to the first word and to the second string of letters. If the second string is a real English word, lift your finger off of the hole. If it is not, do not move your finger. You will have some practice trials before we begin the actual experiment. Do you have any questions?

The insert ear phones were then placed in the subject's ears and the auditory practice and experimental trials were presented.

Data Analysis

Each subject's visual and auditory mean error rates and mean reaction times for correct trials were determined per condition. Responses which were less than 200 msec or greater than 2000 msec were considered outliers and were excluded from the analyses. T-tests were used to compare errors on related and unrelated trials, and errors on auditory and visual trials. To determine if the amount of priming in each condition was significant in the visual task, a 4-way ANOVA with repeated measures was done on the reaction times comparing 1) relatedness, 2) SOA, 3) word class of the prime, and 4) association type. To compare the priming between the conditions, a 3-way ANOVA with repeated measures was done on the amount of priming comparing 1) SOA, 2) word class of prime, and 3) association type. The ANOVAs for the auditory task were similar except that SOA was not a variable. Finally, ANOVAs with repeated measures were done comparing visual and auditory priming for the 650 SOA.

A2. Results and Discussion

Error Data - Visual Paradigm

Subject error rates were extremely low for the visual paradigm. The error rate averaged 1.5% and ranged between

.3% and 3.1%. The number of errors on related trials was not significantly different than the number of errors on unrelated trials ($t(15) = -.87$, $p = .4$, 2-tailed).

Error Data - Auditory Paradigm

Subject error rates were significantly higher for the auditory than for the visual paradigm ($t(15) = -7.85$, $p < .001$, 2-tailed). This effect was not surprising. The quality of these stimuli was more variable due to the available equipment and the restriction that all stimuli be presented in 400 msec. This was done to control the stimulus presentation time more tightly. Holcomb and Neville (1990) did not control for the duration of their auditory stimuli and found equivalent errors across their visual and auditory conditions. However, their visual and auditory error rates were higher than our visual error rates and quite similar to our auditory error rates.

The auditory error rate in this study averaged 5.8% and ranged from 1.7% to 11.3%. A 3-way ANOVA was performed comparing 1) relatedness, 2) first word and 3) association type. A main effect was found for relatedness ($F(1,15) = 19.01$, $p < .001$) indicating that subjects made more errors on unrelated than related trials. The average error

rate for related trials was 2.5% and the average error rate for unrelated trials was 6.5%.

Reaction Time Data - Visual Paradigm

To determine if the priming was significant in each condition, a 4-way Anova was done comparing 1) relatedness, 2) first word, 3) association type and 4) SOA. There was a main effect of relatedness ($F(1,15)=64.51$, $p<.001$) indicating priming. Tukey Post Hocs comparing related and unrelated stimuli found that for the short SOA, there was significant priming for noun/verb, adjective/adjective and adjective/noun (see Table 15). For the long SOA, noun/verb and adjective/adjective conditions had significant priming.

Table 15. Experiment 6. Average reaction times and priming in msec in the visual paradigm by condition.

		<u>650 SOA</u>	<u>1150 SOA</u>
Noun-Noun	Related	722	755
	Unrelated	732	763
	Priming	10	8
Noun-Verb	Related	750	775
	Unrelated	778	812
	Priming	28**	37**
Adjective-	Related	735	744
Adjective	Unrelated	757	781
	Priming	22*	37**
Adjective-	Related	714	729
Noun	Unrelated	738	734
	Priming	24*	5

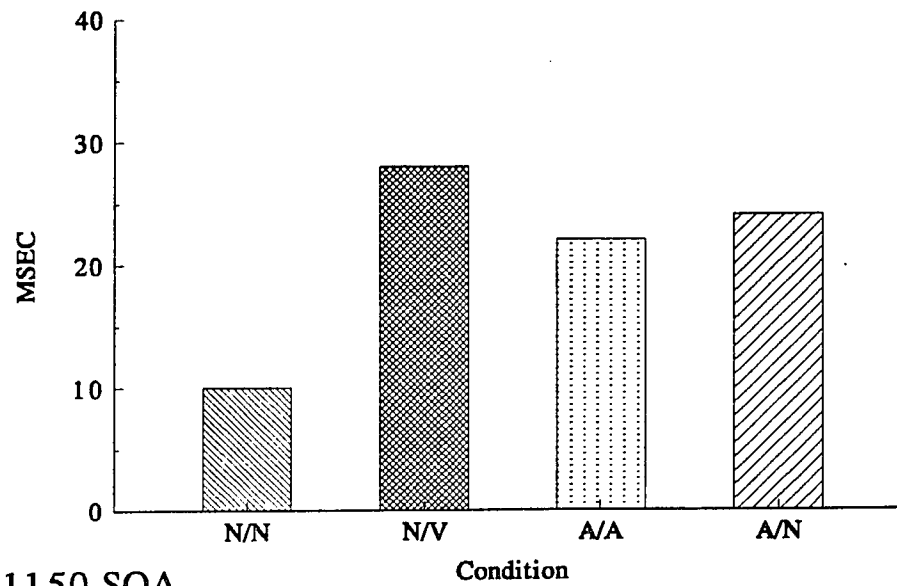
* $p < .05$, ** $p < .01$ on Tukey Post Hocs

There was also a main effect of SOA ($F(1,15)=8.33$, $p < .05$) indicating that the reaction times were faster in the 650 SOA conditions than in the 1150 SOA conditions. SOA was not part of any significant interaction.

There was no main effect of first word or association type. However, the interaction of these two variables was significant ($F(1,15)=11.31$, $p<.05$) and the interaction of these two variables with relatedness was also significant ($F(1,15)=13.99$, $p<.05$). These interactions were not predicted. They indicate that association type is not completely independent of grammatical class. The 3-way interaction will be examined below in an ANOVA which collapses across relatedness.

To compare the priming between conditions, a 3-way ANOVA was computed on the amount of priming comparing 1) first word, 2) association type and 3) SOA. The only significant finding was an interaction between the first word and association type ($F(1,15)=13.99$, $p<.05$). Tukey Post Hocs comparing paradigmatic and syntagmatic stimuli indicated that at the long SOA, there was more noun/verb priming than noun/noun priming and more adjective/adjective than adjective/noun priming. Post Hocs comparing noun and adjective stimuli found that there was more adjective/adjective than noun/noun priming and more noun/verb than adjective/noun priming (see Figure 7). To summarize, for the noun stimuli, there was greater priming for syntagmatic pairs but for the adjective stimuli there was greater priming for the paradigmatic pairs. The differences between conditions were not significant at the short SOA.

650 SOA



1150 SOA

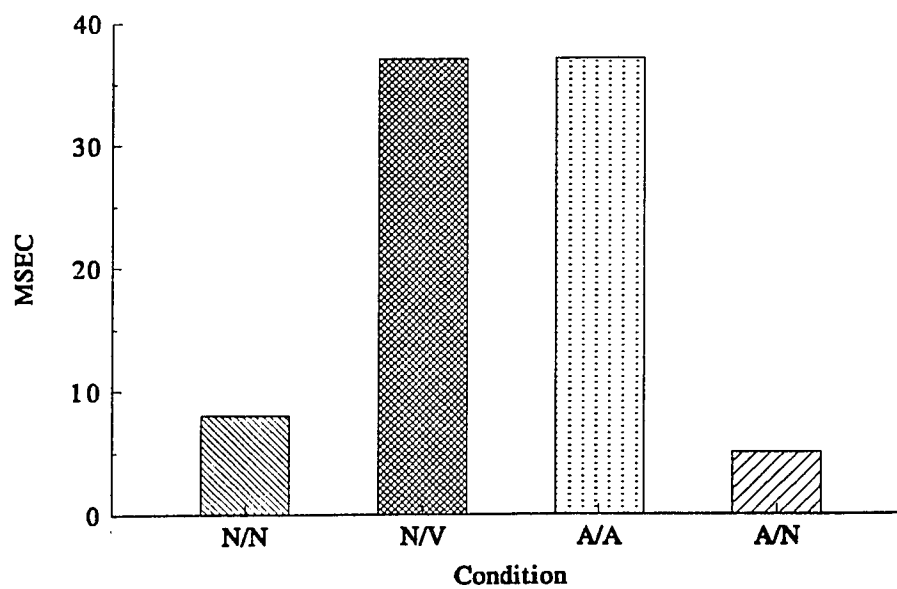


Figure 7. Experiment 6. Two graphs of visual priming by SOA, grammatical class of the prime and association type.

The visual priming results can be summarized as follows. First, as hypothesized, priming was found for adjective/adjective and adjective/noun pairs. Secondly, association type is not completely independent of part of speech. Priming (for longer SOAs) was greatest for noun syntagmatic pairs and adjective paradigmatic pairs and smallest for noun paradigmatic and adjective syntagmatic pairs. Thirdly, the amount of priming does not appear to be related to the SOA.

As noted in the methods section, there was a significant difference between the noun/noun and noun/verb association strengths and a large but nonsignificant difference between the adjective/adjective and adjective/noun association strengths. It is possible that the association strength differences were responsible for the grammatical class/association type interactions. To test this hypothesis, association strength was treated as a covariate in two, 2-way ANOVAs (association type by SOA) on the amount of priming. Only word pairs with normed association strengths were used in this analysis (37 noun/noun/verb and 18 adjective/adjective/noun pairs). The ANOVAs were done separately for the noun sets and the verb sets because of the different number of items in each set. Association strength was not significant in either analysis ($F(1,72)=.05$, $p=.82$ for nouns and $F(1,33)=.27$, $p=.61$ for

adjectives). In addition, there were no significant interactions with association strength. As a result, the association type/grammatical class interaction in the priming data cannot be due to the association strength differences.

Another issue raised in the methods was the presence of seven thematic pairs in the paradigmatic noun/noun stimuli. The average reaction times were recalculated excluding the thematic pairs and the resulting averages were almost identical. For the 650 SOA, the related mean was 724 msec verses 722 msec and the unrelated mean was 734 msec verses 732 msec. For the 1150 SOA, the related mean was 757 msec verses 755 msec and the unrelated mean was 763 msec verses 763 msec.

Reaction Time Data - Auditory Paradigm

To determine if the priming was significant in each condition, a 3-way ANOVA was done comparing 1) first word, 2) association type, and 3) relatedness. A main effect of relatedness ($F(1,15)=151.96$, $p<.001$) was found and Tukey Post Hocs indicated that priming was significant in all conditions (see Table 16).

Table 16. Experiment 6. Average reaction times and priming in msec in the auditory paradigm by condition.

Noun-Noun	Related	648
	Unrelated	729
	Priming	81**
Noun-Verb	Related	666
	Unrelated	798
	Priming	132**
Adjective- Adjective	Related	622
	Unrelated	729
	Priming	107**
Adjective- Noun	Related	693
	Unrelated	774
	Priming	81**

** $p < .01$ on Tukey Post Hocs

A main effect of association type ($F(1,15)=20.64$, $p < .001$) was also found indicating faster responding to paradigmatic pairs. It should be noted that no main effect of association type was seen in the visual reaction times. The 3-way interaction of relatedness, first word and association type ($F(1,15)=11.42$, $p < .01$) was also significant again

demonstrating the absence of association type independence. This interaction was further explored with a 2-way ANOVA which collapsed over relatedness by examining priming.

This ANOVA compared 1) first word and 2) association type and found a significant interaction ($F(1,15)=11.42$, $p<.01$). Tukey Post Hocs comparing paradigmatic and syntagmatic stimuli demonstrated more priming for noun/verb than noun/noun stimuli. Post Hocs comparing noun and adjective stimuli found more priming for noun/verb than adjective/noun stimuli (see Figure 8). To summarize, for the noun stimuli, there was greater priming for syntagmatic pairs but the priming associated with the adjective stimuli was not statistically different between the syntagmatic and paradigmatic conditions.

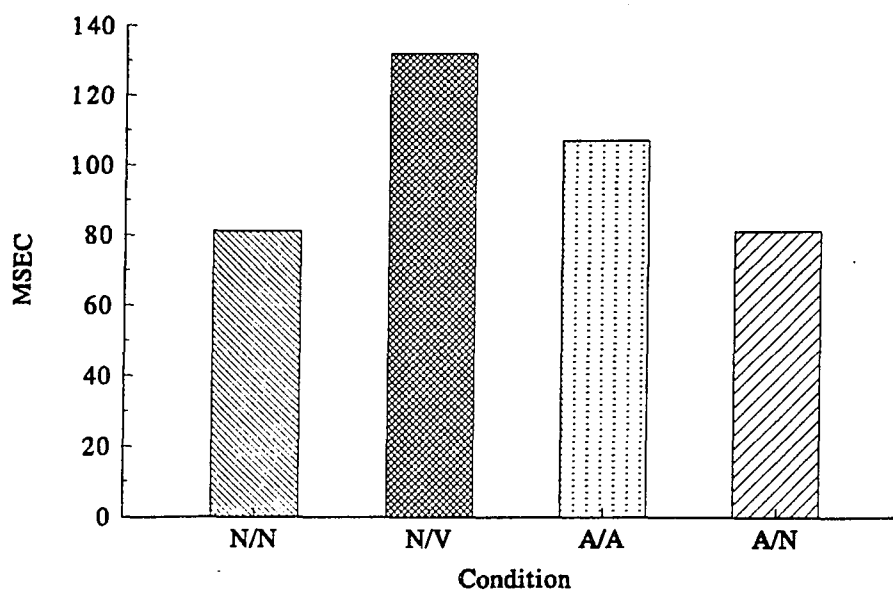


Figure 8. Experiment 6. A graph of auditory priming by grammatical class of the prime and association type.

In summary, the major auditory findings were as follows: 1) As hypothesized, priming was found for all conditions. 2) Again, there was an interaction of association type and grammatical class. The amount of priming was greater for noun syntagmatic pairs than noun paradigmatic pairs but the priming difference between the paradigmatic and syntagmatic adjective pairs was not statistically significant.

Reaction Time Data - Visual Paradigm versus Auditory Paradigm

Auditory and visual presentations were not counterbalanced; auditory presentation always came second. It was possible that the subject's familiarity with the task and the specific words was responsible for any differences in the modalities. To examine this possibility an additional 8 subjects (6 females and 2 males) were tested in the auditory paradigm. Subject requirements were as before. The order of presentation was counterbalanced using the same Latin Square.

A 4-way ANOVA on reaction times was done comparing 1) word class of first word, 2) association type, and 3) relatedness as within subject variables, and 4) auditory second versus auditory only as a between subjects variable. No differences (main effect or interactions) in reaction times were found between the subjects run in the auditory condition when it followed the visual condition and the auditory condition when it was presented alone (main effect: $F(1,22)=.72$, $p=.41$). A similar 4-way ANOVA on error rate also found no main effect of auditory second versus auditory alone. However, an interaction of auditory-second versus auditory-alone and association type was found ($F(1,22)=5.22$, $p<.05$) indicating slightly lower error rate for the

paradigmatic pairs for the auditory-alone subjects (this is possibly due to a fatigue effect, subjects in the auditory-first condition participated for a substantially longer time). Due to the consistency in the auditory-second and the auditory-alone reaction time data, the within-subjects auditory results were used for the following auditory/visual comparisons.

To examine the overall reaction times, a 4-way ANOVA was performed on the 650 SOA visual and the auditory data, comparing 1) word class of the first word, 2) association type, 3) relatedness and 4) presentation modality. The main effect of modality approached significance ($F(1,15)=4.42$, $p=.053$) suggesting faster reaction times to auditorily presented words than to visually presented words (see Table 17).

To compare the priming across modality, a 3-way ANOVA was done on the amount of priming comparing 1) word class of the first word, 2) association type and 3) visual versus auditory presentation. There was a main effect of modality ($F(1,15)=77.39$, $p<.001$) indicating greater auditory than visual priming (see Table 17). It should be noted that the increased priming in the auditory pairs appears to be primarily due to faster responding to related pairs. The 3-way interaction of first word, association type and modality

was also significant ($F(1,15)=5.12$, $p<.05$). This interaction reflects the relative lack of a difference in between condition priming in the visual modality and the strong 2-way interaction seen in the auditory modality.

Table 17. Experiment 6. Average reaction times and priming in msec in the visual and auditory paradigms for the 650 SOA.

		<u>Visual</u>	<u>Auditory</u>
Noun-Noun	Related	722	648
	Unrelated	732	729
	Priming	10	81**
Noun-Verb	Related	750	666
	Unrelated	778	798
	Priming	28**	132**
Adjective- Adjective	Related	735	622
	Unrelated	757	729
	Priming	22*	107**
Adjective- Noun	Related	714	693
	Unrelated	738	774
	Priming	24*	81**

* $p<.05$, ** $p<.01$ on Tukey Post Hocs

In summary, the overall findings for the visual and auditory paradigms were very similar, except that there was much greater priming and faster reaction times in the auditory paradigm. Holcomb and Neville (1990) also found statistically larger auditory than visual priming. It should be noted that in the present study, the increased auditory priming was primarily due to faster responses to related words. The difference between visual and auditory reaction times approached significance ($p=.053$) suggesting faster auditory than visual responses. This is not consistent with the Holcomb and Neville findings. They found that the visual reaction times were on average 105 msec faster than auditory reaction times, but they did not report whether this was a statistically significant difference. The primary difference between their paradigm and the one used in this study is that all of the auditory stimuli were edited to 400 msec duration while their stimuli varied in duration from 270 msec to 700 msec with an average duration of 400 msec. It is possible that this variable stimulus length lead to some uncertainty about when the stimulus was finished, resulting in generally longer processing times.

This experiment has demonstrated a number of things: 1) As predicted, there was priming in both modalities across most conditions (in the visual paradigm, the priming was not

significant for the noun/noun stimuli at both SOAs or for the adjective/noun stimuli at the long SOA). 2) Contrary to the hypotheses, there was an interaction of grammatical class and association types suggesting different underlying processing of nouns and adjectives. 3) With different stimulus sets, different tasks and across visual and auditory presentations, noun/verb priming was greater than noun/noun priming, despite higher noun/noun association strengths. This was contrary to the hypotheses. It is unclear whether the finding of a noun/noun - noun/verb difference is due to the association type or due to the word class of the target. Experiment 9 addressed this issue by reversing the pairs (e.g., cat-dog, bark-dog) so that the final word is the same and only the association type changes.

B. Experiment 7 - Word-Probe, Visual and Auditory Evoked Potential

This experiment examined the N400s associated with the auditory and visual stimuli from Experiment 6. A word-probe task, which is analogous to the letter-probe task in Experiment 5, was used. In this task, the subject was asked if a probe word was a repetition of either the prime or target words. As in Experiment 5, this paradigm was used to separate the P300 and the N400 evoked-potential components

(see Methodological Approaches section). A word probe task was used instead of the letter probe for two reasons: 1) it enabled us to use the same paradigm for the visual and auditory stimuli (an auditory "letter" probe would actually have to be a phoneme probe) and 2) it will allow us to use the same paradigm with children. The SOA used for this experiment was 1150 msec. It was chosen because no N400 effect was seen in 3 experienced subjects in a pilot experiment with a 650 SOA. Because of the large number of trials required for an N400 evoked potential experiment, only one SOA could be used in a within-subject, within-test-session paradigm.

The hypotheses for this experiment were as follows. First, an N400 effect for adjective/adjective and adjective/noun pairs was predicted indicating adjective semantic associations. To date, adjective N400 effects have not been demonstrated in the literature. Second, the N400 effect was predicted to be equal for the two paradigmatic pairs (noun/noun and adjective/adjective) reflecting organizational properties which are independent of word-class. Third, the N400 effect was also predicted to be equal for the two syntagmatic pairs (noun/verb and adjective/noun pairs) again due to general organizational processes. We predicted word-class-independent effects, despite the data from the previous experiments, because 1)

the hypotheses were formed in a general sense before this series of experiments was begun and 2) the data from the methodological studies suggested that priming and N400 effects might be sensitive to different underlying processes (i.e., priming might be word-class dependent and N400 effects might be word-class independent). The fourth hypothesis was that the auditory and visual N400 patterns would be similar, reflecting access of a modality-independent semantic system. Fifth, it was predicted that the topographic distribution of the N400 effect would be different for the paradigmatic and syntagmatic pairs. We expected the syntagmatic pairs to have a more anterior distribution because data from Broca's patients suggest that damage to anterior structures causes syntagmatic deficits and minimal paradigmatic deficits. It was further proposed that the paradigmatic pairs would have a more posterior distribution based on the data from Wernicke's aphasia. Wernicke's patients' have damage to more posterior structures and tend to have paradigmatic deficits and minimal syntagmatic deficits.

B1. Method

Subjects

The subjects were 16 adults (13 females and 3 males), mostly employees at the Albert Einstein College of Medicine.

They ranged in age from 20 to 45. Four of the subjects were also subjects in Experiment 6. All subjects were fluent in English before kindergarten, however, four of the subjects learned English and a second language concurrently. Since the stimuli were presented both visually and auditorily, only subjects with self-reported normal hearing and 20-20 or 20-20 corrected vision, were used. In addition, all subjects were right handed. One subject was excluded because of significant movement artifact which obscured the evoked potentials.

Stimuli

i. Visual Stimuli

The 40 visual related and unrelated noun/noun, noun/verb, adjective/adjective and adjective/noun word pairs from Experiment 6 were used. The prime and target were separated by an 1150 msec SOA.

A delayed word probe task was used to separate the N400 and the P300 and to insure that subjects attended to the stimuli. The third word was presented 1200 msec after the word pair (there was then a 3 second SOA before the next prime). The word was either one of the words in the word pair ("yes" condition) or a word from a different word pair

("no" condition). Half of the pairs were randomly assigned to the "yes" condition and half to the "no" condition. In the "yes" condition, half of the probes were repetitions of the prime and half were repetitions of the target. This task was designed to be relatively easy so that in the future it could be used with 7, 8 and 9 year-old children.

These manipulations resulted in four blocked sets of word pairs: noun/noun, noun/verb, adjective/adjective, and adjective/noun. Each set contained 40 related pairs and 40 unrelated pairs with 40 repetition probes and 40 novel probes.

Within each set, the word pairs were randomly ordered with the restrictions that not more than three related or unrelated pairs could occur in sequence and that not more than three "yes" or "no" word probe trials could occur in sequence.

ii. Auditory Stimuli

The 24 auditory noun/noun/verb sets and the 29 auditory adjective/adjective/noun sets from Experiment 1 were used. Because larger Ns are required for evoked potential studies, an additional 16 noun/noun, 16 noun/verb, 11 adjective/adjective and 11 adjective/noun word pairs were added.

These words pairs were from the original non-cued lexical decision study. They had not been used in the auditory lexical decision study for one of two reasons: 1) because the visual set had been excluded (8 noun sets and 6 adjective sets), or 2) because one of the words in the auditory set was ambiguous or was excluded because the response times were greater than 2SD from the mean (3 noun/noun, 5 noun/verb, 5 adjective/adjective). The use of the stimuli which had been excluded from the auditory lexical decision task, was not considered problematic because of the task differences. In this task, the assumption was that all of the stimuli were words, whereas in the lexical decision task, the subject had to decided if the stimulus was a word. The additional stimuli are in Appendix F.

Unrelated pairs were created, as in Experiment 6. Word pairs were randomly ordered to create blocked lists, probe conditions were randomly assigned and probe words were determined in the same manner as in the visual paradigm.

A Latin Square design was used to counterbalance grammatical class of the first word and association type and to create four presentation orders: 1) n/n, n/v, a/a, a/n; 2) a/a, n/n, a/n, n/v; 3) n/v, a/n, n/n, a/a; and 4) a/n, a/a, n/v, n/n. Presentation modality was blocked, with half

of the subjects receiving the visual trials first and half receiving the auditory first. Presentation order, as determined by the above Latin Square, was the same for the visual and auditory sets.

Procedure

Subjects were tested in one session which lasted approximately 3 hours. The procedure was similar to Experiment 6, except that the subjects were told that three words would be presented and that their task was to decide if the third word was the same as either the first or second words.

EEG Recording Procedure

A cap (Electro-Cap International) containing 30 tin electrodes was fitted to the subject's scalp. The electrode placements were standard International 10-10 system (new modified combinatorial nomenclature, American Electroencephalographic Society, 1990) locations: Fpz, Fp1, Fp2, Fz, F3, F4, F7, F8, FC1, FC2, FC5, FC6, Cz, C3, C4, T3, T4, LM (left mastoid), RM (right mastoid), CP1, CP2, CP5, CP6, Pz, P3, P4, P7 (old T5), P8 (old T6), O1, O2 (see Figure 9). Two additional electrodes were attached at the left and right outer canthi to monitor horizontal eye

movements. Vertical eye movements were monitored at Fp1 and Fp2. A nose electrode served as the reference. All impedances were maintained at less than 5 kOhms. A Nicolet Pathfinder I computer was used to record and analyze the evoked potentials. The recording epoch was 1300 msec, beginning 200 msec before the onset of the target word. The sampling interval was 5.2 msec.

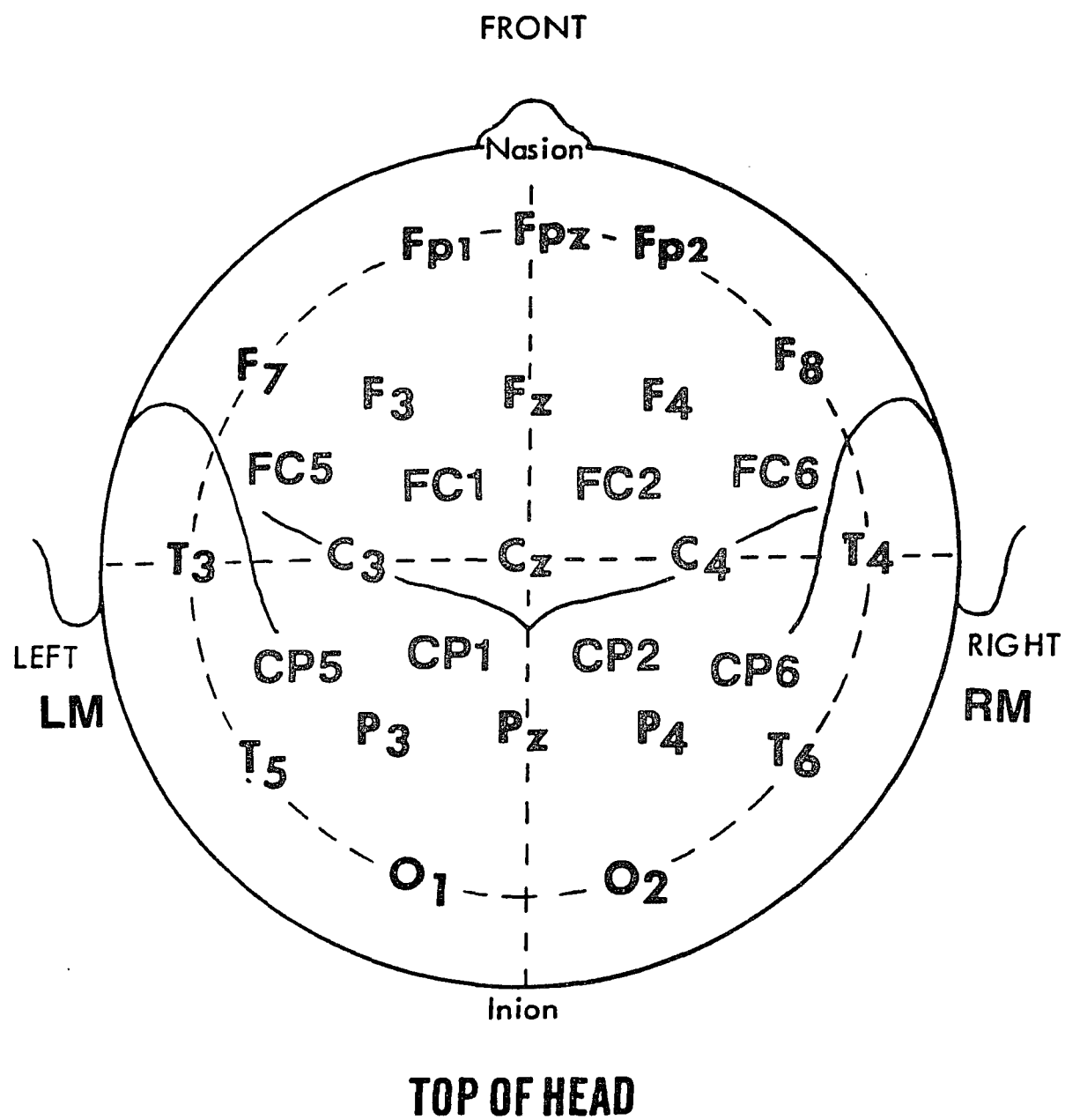


Figure 9. Recording electrodes.

Offline, the evoked potentials from correct trials which were free of eye movement and muscle artifact, were averaged by condition for each subject.

Data Analysis

Mean reaction times and accuracy rates for the word probes were determined and compared across presentation modalities. Mean amplitudes of the averaged evoked potentials were calculated for a 350 to 450 msec window. This window was selected by examining the grand means averaged across condition at Cz for the related and unrelated trials and determining the window which included the largest separation between the related and unrelated waves. To determine if the N400 effect (as discussed above, the N400 effect was defined as the difference between the related and unrelated N400 mean amplitudes) was significant in each condition, 4-way ANOVAs with repeated measures were calculated on mean amplitude separately for the visual and auditory trials. The factors were grammatical class of the first word, association type, relatedness and electrode. For these analyses, the eight electrodes where the N400 effect was expected to be largest, were used (Cz, Pz, C3, C4, CP1, CP2, P3, P4). To compare the N400 effect between conditions, 3-way ANOVAs with repeated measures were

calculated on the N400 effect comparing first word, association type and electrode.

In order to test the hypotheses of different topographical distributions of activity for the two association types, 3-way ANOVAs with repeated measures were calculated. The factors were grammatical class of the first word, association type and electrode. The electrodes used were the eight anterior electrodes (FP1, FPz, FP2, F7, F3, Fz, F4, F8) and the seven posterior electrodes (T5, P3, Pz, P4, T6, O1, O2). The amplitude at these electrodes was scaled by subject, by dividing them by the value of the largest amplitude in the set to get the percent of maximal amplitude (Ritter, Simson & Vaughan, 1988) which was then entered into the ANOVA.

Finally, ANOVAs with repeated measures were calculated comparing the visual and auditory data. The Geisser-Greenhouse correction was applied to all repeated measures with greater than 1 degree of freedom. This correction is generally applied to analyses of evoked potential measures to adjust a priori for the expected violation of the homogeneity assumption. This assumption is usually violated because the evoked potentials collected from multiple electrodes on the same individual are correlated.

B2. Results and Discussion

Word-Probe Data

As expected, subject error rates were low for both visual and auditory paradigms. The average error rates were 3.8% (2.8 SD) for the visual paradigm and 2.6% (2.1 SD) for the auditory paradigm. A t-test comparing the visual and auditory error rates was not significant ($t(15)=-1.44$, $p=.17$, 2-tailed).

The mean reaction times to the word probes were significantly faster in the auditory paradigm than in the visual paradigm ($t(15)=-7.12$, $p<.001$, 2-tailed). The mean response time for the visual paradigm was 594 msec (74 SD) and for the auditory paradigm was 490 msec (90 SD).

N400 Data - Visual Paradigm

To determine if the N400 effect was significant for each condition, a 4-way ANOVA on the mean amplitudes (in the 350-450 msec window) was calculated. The four factors were grammatical class of the first word, association type, relatedness and electrode (the eight electrodes where N400 is usually largest were used). There were three main effects. A main effect of relatedness ($F(1,15)=9.30$, $p<.01$)

was found indicating an overall N400 effect. Tukey Post Hocs found that the N400 effect was significant at all eight electrodes for all conditions (see Table 18, Figure 10, and Appendix F). Also significant was a main effect of association type ($F(1,15)=4.71$, $p<.05$) which identified the greater negativity in the syntagmatic pairs, particularly in the adjective/noun pairs, and a main effect of electrode ($F(7,105)=5.53$, $p<.01$). No other main effects or interactions were significant.

Table 18. Experiment 7. The N400 effect in uV by electrode by condition for the visual paradigm.

	<u>Noun/Noun</u>	<u>Noun/Verb</u>	<u>Adj/Adj</u>	<u>Adj/Noun</u>
Cz	.77**	1.20**	1.21**	1.51**
Pz	.66**	1.15**	1.28**	1.72**
C3	.55**	.64**	.85**	1.39**
C4	.80**	.93**	.61**	1.27**
Cp1	.46**	1.13**	1.03**	1.73**
Cp2	.75**	1.10**	.99**	1.51**
P3	.58**	.95**	.93**	1.83**
P4	.58**	.94**	.89**	1.81**

** $p<.01$ on Tukey Post Hocs

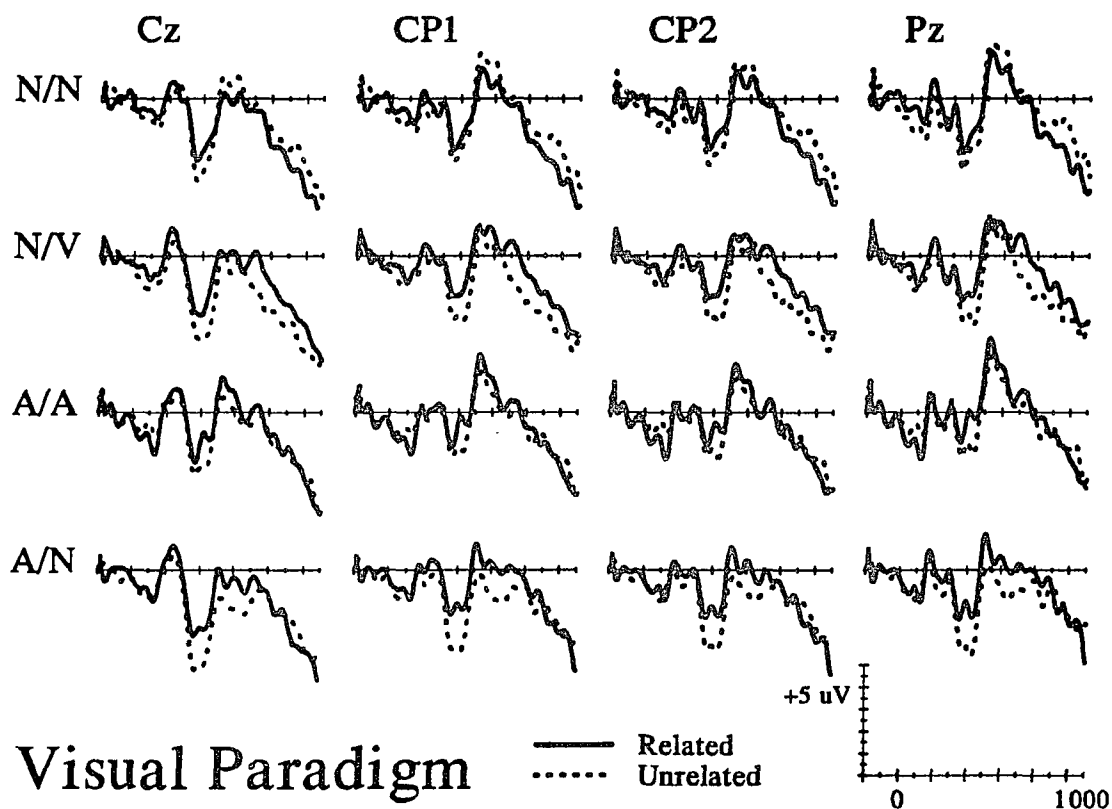


Figure 10. Experiment 7. Grand mean evoked potentials elicited in the four visual conditions. The target word was presented at time zero.

A 3-way ANOVA designed to examine the size of the N400 effect across conditions, found no main effects or interactions. The factors were grammatical class of the first word, association type and electrode (the same eight electrodes as in the above analysis).

A 3-way ANOVA was calculated on the scaled amplitude values to test the topographic distribution hypothesis. The factors were grammatical class of the first word, association type and electrode. The electrodes used were those defined in the Data Analysis section. No significant interaction with electrode was found. Because the reaction time data discussed in Experiment 6 suggest differences across grammatical class, two additional analyses examined the noun stimuli and the adjective stimuli separately. Neither the noun nor the adjective 2-way ANOVA found an interaction with electrode. This does not necessarily imply that the underlying brain generators are the same, but only that the spatial summation of the generators measured at the scalp were not differentiable.

A comparison of the N400 effect and priming data, both for an 1150 SOA, showed somewhat different patterns of results (see Table 19). Priming was largest for the noun/verb and adjective/adjective conditions and was not significant for the noun/noun and adjective/noun conditions.

The N400 effect was present in all conditions and was not statistically different between conditions. This difference between the N400 effect and priming data again suggests that there may be different mechanisms responsible for the two phenomena. However, it should be noted that both the priming and the N400 effects were in the same direction and that different tasks and different subjects were used in the two experiments. It is possible that the N400 effect/behavioral priming differences were due only to variability.

Table 19. A comparison of the visual N400 effect in uV (at Cz) from Experiment 7 and the visual priming in msec from Experiment 6 for the 1150 SOA.

		<u>N400</u>	<u>Priming</u>
Noun-Noun	Related	-2.46	755
	Unrelated	-3.23	763
	Difference	.77**	8
Noun-Verb	Related	-2.42	775
	Unrelated	-3.62	812
	Difference	1.20**	37**
Adjective- Adjective	Related	-1.47	744
	Unrelated	-2.68	781
	Difference	1.21**	37**
Adjective- Noun	Related	-2.61	729
	Unrelated	-4.12	734
	Difference	1.51**	5

** $p < .01$ on Tukey Post Hoc

In summary, as predicted, the N400 effect was significant for the adjective/adjective and the adjective/noun stimuli, as well as for the noun/noun and the noun/verb stimuli. In addition, the size of the effect was

statistically equal for all four conditions. In contrast, the size of the priming effect was dependent upon an interaction of the grammatical class of the first word and the association type. Finally, there was no indication of a topographical difference for the visual N400 effects.

N400 Data - Auditory Paradigm

To determine if the N400 effect was also significant for each condition in the auditory paradigm, a four-way ANOVA was calculated with the following factors: 1) grammatical class of the first word, 2) association type, 3) relatedness and 4) electrode (the same eight as in the visual analyses). A main effect of relatedness was again found ($F(1,15)=5.51$, $p<.05$) indicating an overall N400 effect. Tukey Post Hocs indicated that the N400 effect was significant at all electrodes for the noun/noun, noun/verb, and adjective/adjective stimulus pairs (see Table 20, Figure 11 and Appendix F). The effect was not significant for the adjective/noun stimuli and was actually in the reverse direction at most electrodes.

Table 20. Experiment 7. The N400 effect in uV by electrode by condition for the auditory paradigm.

	<u>Noun/Noun</u>	<u>Noun/Verb</u>	<u>Adj/Adj</u>	<u>Adj/Noun</u>
Cz	.99**	2.21**	1.19**	.27
Pz	.96**	1.99**	1.81**	-.26
C3	.59**	1.69**	.92**	-.35
C4	.60**	1.61**	1.08**	.02
Cp1	.92**	1.98**	1.27**	-.11
Cp2	.90**	1.80**	1.44**	-.05
P3	.86**	1.83**	1.43**	-.46*
P4	.92**	1.70**	1.78**	-.33

* $p < .05$, ** $p < .01$ on Tukey Post Hocs

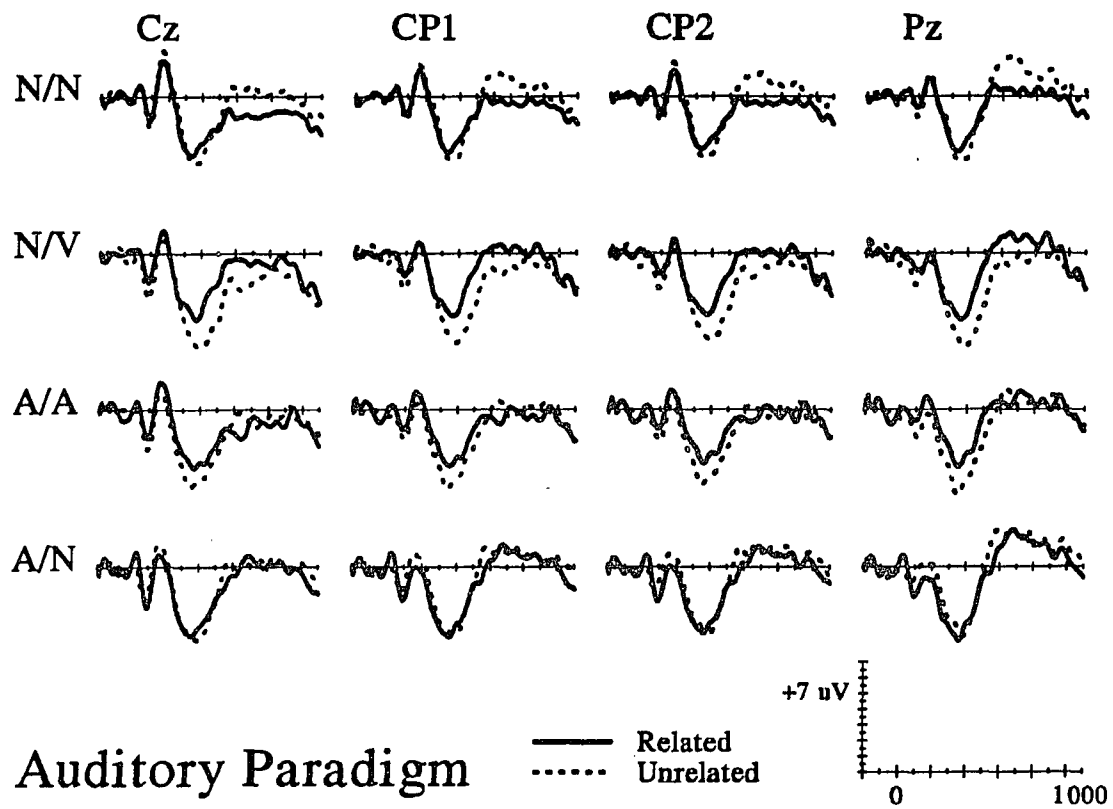


Figure 11. Experiment 7. Grand mean evoked potentials elicited in the four auditory conditions. The target word was presented at time zero.

A main effect of association type ($F(1,15)=7.65$, $p<.05$) was again found identifying greater syntagmatic negativity, particularly for the noun/verb stimuli. A main effect of electrode ($F(7,105)=5.41$, $p<.05$) was also found. No other main effects or interactions were significant.

To compare the N400 effect between conditions, a 3-way ANOVA was computed for the N400 effect on first word, association type and electrode. The main effect of electrode ($F(7,105)=2.62$, $p=.065$) and the interactions of first word and association type ($F(1,15)=2.97$, $p=.10$) and of association type and electrode ($F(7,105)=2.50$, $p=.08$) approached significance. It was decided to further explore the interaction of first word and association type, although it only approached significance, because it was similar to the interactions seen in the priming data. Tukey Post Hocs comparing syntagmatic and paradigmatic stimuli found that the noun/verb N400 effect was larger than the noun/noun N400 effect but that the adjective/adjective N400 effect was larger than the adjective/noun N400 effect. Post Hocs comparing noun and adjective stimuli found that the noun/verb N400 effect was larger than the adjective/noun N400 effect and that the noun/noun and adjective/adjective N400 effects were statistically equal.

The topographic distribution of the N400 effect was examined using the procedure described above in the Data Analysis section. There were no significant interactions with electrode. Separate analyses for the noun and adjective stimuli also found no significant electrode interactions. Again, this does not necessarily imply that the underlying generators are the same.

The auditory priming study was done with a short SOA (650 msec) so a comparison of the N400 and priming effects could not be done. Experiment 8, discussed below, is an auditory priming study with an 1150 SOA. The N400 effect/priming comparison will be discussed there.

In summary, the N400 effect in the auditory modality was significant for the noun/noun, noun/verb, and adjective/adjective stimuli but not for the adjective/noun stimuli. In addition, the N400 effect was larger for the noun syntagmatic than the noun paradigmatic stimuli and larger for the adjective paradigmatic than the adjective syntagmatic stimuli. This N400 effect pattern was similar to the pattern seen in the priming data. There were no indications of topographic differences.

N400 Data - Visual Paradigm versus Auditory Paradigm

To compare the size of the N400 effect across modality, two 3-ways ANOVAs were calculated examining the size of the N400 effect at Cz and Pz across modality, first word, and association type. No main effect of modality or significant interactions with modality was found (see Table 21). The absence of a main effect of modality ($F(1,15)=.02$, $p=.90$ at Pz and $F(1,15)=.00$, $p=.99$ at Cz) indicates that there is no overall difference between the visual and auditory N400 effects. This is in contrast to Holcomb and Neville (1990) who found that the N400 was larger in the auditory than in the visual condition. However, it should be noted that their finding was based on the mean amplitude in a window from 200 to 700 msec. This is a much larger window than is usually used to examine the N400 effect (in fact within modality, Holcomb and Neville used a 300 to 500 msec window) and also encompasses the area of the P300. As a result, it is possible (and appears probable, see Figure 5) that their difference is at least partially due to a P300 modality difference.

Table 21. Experiment 7. The N400 effect in uV (at Cz) for the visual and auditory paradigms.

		<u>Visual</u>	<u>Auditory</u>
Noun-Noun	Related	-2.46	-3.15
	Unrelated	-3.23	-4.14
	Difference	.77**	.99**
Noun-Verb	Related	-2.42	-3.70
	Unrelated	-3.62	-5.90
	Difference	1.20**	2.20**
Adjective- Adjective	Related	-1.47	-3.45
	Unrelated	-2.68	-4.64
	Difference	1.21**	1.19**
Adjective- Noun	Related	-2.61	-4.27
	Unrelated	-4.12	-4.54
	Difference	1.51**	.27

** $p < .01$ on Tukey Post Hoc

The topographies of the visual and the auditory N400 effects were also compared. A 4-way Anova was calculated on the scaled amplitude values comparing presentation modality, grammatical class, association type and electrode. Nine widely distributed electrodes were used for this analysis

(FPz, F3, Fz, F4, P3, Pz, P4, O1, O2). There was no interaction of modality and electrode ($F(8,120)=.28$, $p=.78$). Holcomb and Neville (1990) also found no modality differences in topography.

In summary, the overall findings for the visual and auditory paradigms were similar, except for the modality difference in the N400 effect for adjective/noun pairs.

This experiment has also demonstrated a number of other things: 1) An N400 effect was found in both modalities for all conditions except for the adjective/noun condition in the auditory modality. 2) Again, there appears to be an interaction of grammatical class of the first word and association type in the auditory paradigm, however, it only approached significance. There was no interaction in the visual paradigm. 3) Contrary to the hypotheses, there was no indication of topographic differences in either modality.

C. EXPERIMENT 8 - Auditory, 1150 SOA, Lexical Decision

As discussed above, this study was done to have an auditory priming study with the same SOA as the evoked potential experiment so that priming and N400 effects could be compared. In addition, the study was done in such a way

that the results could also be compared to the 650 msec SOA priming study.

C1. Method

Subjects

The subjects were 16 adults (12 females and 4 males) who were mostly employees at the Albert Einstein College of Medicine. They ranged in age from 20 to 45. Six of the subjects had been subjects in Experiment 6 and 6 of the subjects had been subjects in Experiment 7. The subject criteria were the same as for Experiment 6.

Stimuli

The stimuli were the set of auditory stimuli used in Experiment 6 plus the stimuli added for Experiment 7. The stimuli from Experiment 6 were presented in the order established in that experiment. The additional stimuli from Experiment 7 were randomly reorganized to create unrelated pairs and were paired with nonwords to create word/nonword pairs. Within each set, the pairs were then randomly ordered. These procedures were done in the same manner as in Experiment 6. All stimulus pairs were presented with an 1150 msec SOA. The time between stimulus pairs was again 3

seconds. The condition presentation orders were the same as in Experiment 6.

Procedure

Subjects were tested in one session which lasted approximately 1 hour and 15 minutes. The procedure was the same as in Experiment 6, except that only auditory trials were presented. Experiment 9 immediately followed.

Data Analysis

Each subject's mean reaction times for correct trials were determined for the stimuli from Experiment 6 and from Experiment 7. As before, responses which were less than 200 msec or greater than 2000 msec were considered outliers and were excluded from the analyses. Mean error rates were also calculated. Three-way ANOVAs with repeated measures were calculated for mean reaction times and error rates comparing 1) relatedness, 2) first word, and 3) association type. To compare priming across conditions, a 2-way ANOVA with repeated measures was performed for the amount of priming comparing 1) word class of prime and 2) association type. Finally, between-subject ANOVAs with repeated measures were done comparing the data from this experiment and the 650 SOA auditory data from Experiment 6.

C2. Results and Discussion

Error Data

The error rate averaged 6.7% and ranged from 3.0% to 9.5%. A 3-way ANOVA was done comparing 1) relatedness, 2) first word and 3) association type. A main effect of relatedness was found ($F(1,15)=20.52$, $p<.001$) due to the greater number of errors on unrelated than related trials. The average number of errors on related trials was .7 and on unrelated trials was 2.4.

Reaction Time Data - Experiment 7 Stimuli

To determine if the priming for Experiment 7 stimuli was significant in each condition, a 3-way Anova was computed comparing the effects of 1) relatedness, 2) first word, and 3) association type. There was a significant main effect of relatedness ($F(1,15)=104.50$, $p<.001$) indicating priming. Tukey Post Hocs comparing related and unrelated stimuli found that there was significant priming for noun/noun, noun/verb, adjective/adjective and adjective/noun pairs (see Table 22). There was also a main effect of association type ($F(1,15)=5.00$, $p<.05$) indicating faster paradigmatic reaction times. In addition, there were two significant interactions. The interaction of first word and

association type ($F(1,15)=10.85$, $p<.01$) was significant, again demonstrating that association type is not independent of grammatical class. The second significant interaction was between association type and relatedness ($F(1,15)=11.67$, $p<.01$). It is further explored below in the 2-way ANOVA examining priming.

To compare priming across conditions, a 2-way ANOVA was done on the amount of priming comparing 1) first word and 2) association type. The only significant finding was a main effect of association type ($F(1,15)=11.67$, $p<.01$) indicating larger paradigmatic priming (see Table 22). Tukey Post Hocs found that the priming was only significantly different for the adjective/adjective and adjective/noun stimuli. Adjective/adjective priming was significantly larger than the adjective/noun priming.

Table 22. A comparison of the auditory N400 effect in uV (at Cz) from Experiment 7 and the auditory priming in msec from Experiment 8 for the 1150 SOA.

		<u>N400</u>	<u>Priming</u>
Noun-Noun	Related	-3.15	596
	Unrelated	-4.14	687
	Difference	.99**	91**
Noun-Verb	Related	-3.70	651
	Unrelated	-5.90	720
	Difference	2.20**	69**
Adjective- Adjective	Related	-3.45	607
	Unrelated	-4.64	697
	Difference	1.19**	90**
Adjective- Noun	Related	-4.27	634
	Unrelated	-4.54	678
	Difference	.27	44**

** $p < .01$ on Tukey Post Hocs

A comparison of the auditory N400 effect and priming data, both for an 1150 SOA, showed a remarkably similar pattern of results (see Table 22). Priming was significant in all four conditions but was smallest in the

adjective/noun condition. The N400 effect was significant in the noun/noun, noun/verb, and adjective/adjective conditions, but not in the adjective/noun condition.

Reaction Time Data - Experiment 6 Stimuli

To determine if the priming for Experiment 6 stimuli was significant in all conditions, a 3-way Anova was done comparing 1) relatedness, 2) first word, and 3) association type. There was a main effect of relatedness ($F(1,15)=126.65$, $p<.001$) indicating priming. Tukey Post Hocs comparing related and unrelated stimuli found that there was significant priming for noun/noun, noun/verb, adjective/ adjective and adjective/noun pairs (see Table 23). There was also a main effect of association type ($F(1,15)=6.78$, $p<.05$) indicating faster paradigmatic reaction times. In addition, there was a significant interaction of association type and relatedness ($F(1,15)=10.11$, $p<.01$) indicating larger paradigmatic priming.

To compare the priming across conditions, a 2-way ANOVA was done on the amount of priming comparing 1) first word and 2) association type. The only significant finding was the main effect of association type ($F(1,15)=10.11$, $p<.01$). Tukey Post Hocs indicate that this effect of larger

paradigmatic priming was significant for both nouns and adjectives.

Two ANOVAs were done to examine the data from the 650 and the 1150 SOA experiments. A 4-way ANOVA was performed with first word, association type and relatedness as within subject variables and SOA as a between subjects variable. There was a main effect of SOA ($F(1,30)=4.22$, $p<.05$) indicating faster 1150 SOA reaction times (see Table 23). Tukey Post Hocs found that the differences were significant for all conditions. However, the effect appears to be due to subject and situational variables rather than SOA. This assessment was based on the fact that a main effect of experiment due to faster reaction times by Experiment 8 subjects, was also seen in an ANOVA comparing two experiments with the same SOA (see Experiment 9 results). These differences may have confounded the results. There were three significant interactions with SOA: relatedness and SOA ($F(1,30)=7.00$, $p<.05$), association type, relatedness and SOA ($F(1,30)=7.53$, $p<.05$) and association type, relatedness, first word and SOA ($F(1,30)=5.80$, $p<.05$). All of the interactions were with relatedness and will be explored in the ANOVA on priming below.

Table 23. A comparison of the auditory priming in msec for the 650 SOA from Experiment 6 and for the 1150 SOA from Experiment 8.

		<u>650 SOA</u>	<u>1150 SOA</u>
Noun-Noun	Related	648	590
	Unrelated	729	679
	Priming	81**	89**
Noun-Verb	Related	666	644
	Unrelated	798	699
	Priming	132**	55**
Adjective- Adjective	Related	622	581
	Unrelated	729	678
	Priming	107**	97**
Adjective- Noun	Related	693	629
	Unrelated	774	680
	Priming	81**	51**

** $p < .01$ on Tukey Post Hocs

To compare the priming across SOA, a 3-way ANOVA was done on the priming. There was a main effect of SOA ($F(1,30)=7.00$, $p < .05$) due to larger priming at the 650 SOA. Tukey Post Hocs found that the difference was only

significant in the noun/verb and the adjective/noun conditions. Because this effect was only significant in the syntagmatic pairs, there was an interaction of association type and SOA ($F(1,30)=7.53$, $p<.05$). Finally, there was a second interaction with SOA: association type, first word and SOA ($F(1,30)=5.80$, $p<.05$). This interaction was primarily due to two SOA differences. First, noun/verb priming was larger than noun/noun priming in the 650 SOA condition, but noun/noun priming was larger than noun/verb priming in the 1150 SOA condition. Second, noun/verb priming was larger than adjective/noun priming in the 650 SOA condition, but noun/verb and adjective/noun priming were statistically equal in the 1150 SOA condition.

In summary, there were some significant differences between the 650 and the 1150 SOA data. The major finding, however, was that all of the reaction times were significantly faster at the 1150 SOA than at the 650 SOA. This appears to be due to subject and situational variables and suggests that the other SOA differences may be confounded. These two conditions should be replicated in a within subject paradigm and the auditory SOA differences should be considered with respect to the visual SOA results which were completely within subjects.

D. EXPERIMENT 9 - Reversed, 650 SOA Lexical Decision

As mentioned above, this study was done to determine if the priming differences seen in Experiment 6 and 8 were due to association type or the grammatical class of the target word. This study was conducted after Experiment 8 with the same subjects.

D1. Method**Subjects**

The subjects were the same as in Experiment 8.

Stimuli

The stimuli were the set of noun/noun and noun/verb auditory stimuli used in Experiment 6, except that the order of presentation of the words in the word pairs was reversed (i.e., the primes became the targets and the target became the primes). For example, the pair "dog-cat" became "cat-dog" and "dog-bark" became "bark-dog". This was done so that the targets would be the same across conditions. So that primes would consistently be primes and targets consistently targets, the first words in the Experiment 6 word/nonword pairs were exchanged for their related pair

(e.g., "dog-mouple" became "cat-mouple"). All stimulus pairs were presented with an 650 msec SOA. The time between stimulus pairs was again 3 seconds. Half of the subjects received the noun/noun stimuli first and half received the verb/noun stimuli first.

Procedure

This experiment followed Experiment 8, but otherwise the procedure was the same as Experiment 8.

Data Analysis

Each subject's mean error rates and mean reaction times for correct trials were determined. As before, responses which were less than 200 msec or greater than 2000 msec were considered outliers and were excluded from the analyses. Mean errors and reaction times were examined using 2-way ANOVAs with repeated measures comparing 1) relatedness and 2) association type. In addition, two ANOVAs with repeated measures (a 3-way and a 2-way) were performed to compare the reaction times and priming from Experiment 9 and the auditory, 650 SOA condition from Experiment 6.

D2. Results and Discussion

Error Data

The error rate in this study averaged 5.2% and ranged from 1.0% to 13.5%. A 2-way ANOVA was done comparing 1) relatedness and 2) association type. A main effect was found for relatedness ($F(1,15)=15.45$, $p<.001$) indicating that subjects made more errors on unrelated than related trials. The average number of errors on related trials was .5 and on unrelated trials was 1.3.

Reaction Time Data

To determine if the priming was significant in both conditions, a 2-way ANOVA comparing relatedness and association type was done. A main effect of relatedness ($F(1,15)=62.99$, $p<.001$) was found indicating priming (see Table 24). The priming was significant for both conditions, according to the Tukey Post Hocs. There was also a main effect of association type ($F(1,15)=6.14$, $p<.05$) due to the faster paradigmatic reaction times.

A 3-way ANOVA was done to compare the reaction times from Experiment 9 and the auditory, 650 SOA condition from Experiment 6. As mentioned above in Experiment 8, there was

a main effect of experiment ($F(1,30)=13.92$, $p<.01$) due to the faster reaction times in Experiment 9 (see Table 24). Tukey Post Hocs found that the difference was significant for all comparisons. This effect is thought to be due to subject and situational variables (these subjects were tested for a shorter time than those in Experiment 6). There was also one interaction with experiment: experiment by relatedness ($F(1,30)=6.53$, $p<.05$) which was further explored in the ANOVA on priming below.

Table 24. A comparison of the auditory priming in msec from Experiment 6 and from Experiment 9.

		<u>Reversed</u>	<u>Experiment 6</u>
Noun-Noun	Related	529	648
	Unrelated	591	729
	Priming	62**	81**
Noun-Verb	Related	559	666
	Unrelated	647	798
	Priming	88**	132**

** $p<.01$ on Tukey Post Hocs

A 2-way ANOVA compared the priming across Experiments 6 and 9. A main effect of experiment was found ($F(1,30)=6.53$, $p<.05$) indicating larger priming in Experiment 6. Tukey

Post Hoc tests found that the difference was only significant for the noun/verb pairs. This finding again indicates an interaction of association type and word class. The priming difference associated with the targets which differed in both association type and grammatical class, was larger than that associated with stimuli which only differed in association type. This suggests that there was an effect of grammatical class.

E. General Discussion of Theoretical Experiments

There were six behavioral and five electrophysiological hypotheses advanced in the theoretical experiments. These hypotheses and the experimental results will be discussed and, where appropriate, compared to the results found in the literature.

E1. Behavioral Hypotheses

The first hypothesis was that all four conditions (noun/noun, noun/verb, adjective/adjective and adjective/noun) would elicit priming in both modalities. Priming was seen for most conditions but was not significant for the noun/noun pairs in either of the visual conditions (650 and 1150 SOA) or for the adjective/noun pairs in the visual, 650 SOA condition (see Tables 15 and 23). However,

even in these cases, the priming effect was consistently in the predicted direction. These findings are the first examining priming as a function of association type and grammatical class of the prime and target.⁶ Most previous studies have employed stimulus sets which were mixed with respect to grammatical class and association type (Besner, Smith & MacLeod, 1990; Holcomb & Neville, 1990). These stimulus sets were usually primarily paradigmatic and often predominantly made up of noun/noun and adjective/adjective pairs (e.g., Besner et al. used 88% paradigmatic, 58% noun/noun and 18% adjective/adjective pairs). However, a couple of studies have used stimulus sets which were strictly categorical and, as a result, mainly noun/noun (Lupker, 1984; Hodgson, 1991; Howard, McAndrews, & Lasaga, 1981). The amount of noun/noun priming found in these studies ranges from 5 msec (Hodgson) to 63 msec (Howard et al.). It should be recalled that this study found 10 and 8 msec of visual noun/noun priming for the 650 SOA and 1150 SOA conditions, respectively.

Despite the present lack of significant results for visual noun/noun priming, it is thought that the small amount of priming that we found was real. There are three

⁶ A few studies (e.g., Becker, 1980; Hodgson, 1991) have examined the priming associated with different types of "lexical relations" (Hodgson, p. 175). But these association types have crossed grammatical boundaries.

findings which support this belief. First, the amount of noun/noun priming found in our visual experiments was comparable in size to previous studies. Second, the amount of priming in our experiments was consistent between the two visual conditions. Finally, significant noun/noun priming was found in the auditory paradigm, though here also the size of the priming was usually less than that in the other conditions.

Assuming that noun/noun priming has been elicited, one can ask why it is often so small. There are three possible explanations. First, it is possible that there is something inherent in noun/noun associations which results in less priming (e.g., nouns could be so heavily interconnected in the semantic network, that each connected node only receives a minimal amount of activation). However, this is unlikely given the 63 msec of priming found in the Howard study. Second, different types of noun/noun associations might elicit varying amounts of priming. Both Lupker (1984) and Alarabel, Pitarque, Soler, Ruiz, Baixauli and Dasi (1987) have examined priming in associated pairs which were not from the same category (e.g., "camel" - "hump") and in category pairs (e.g., "ear" - "nose" or "animal" - "lion"). Neither study found any differences in priming, but both studies presented the stimuli in a mixed manner. This leads to the third explanation. It is possible that the number of

different types of noun/noun associations within a stimulus list can effect the amount priming elicited. These second two explanations will be further explored.

There have been a variety of different classification schemes for association types (for example Moran, 1981; Clark, 1970), but the most detailed is the one developed by Woodrow and Lowell (1916). Based on word association data from children and adults, they defined the following classification categories: 1) superordination (e.g., "table" - "furniture"), 2) subordination (e.g., "fruit" - "apple"), 3) coordination (e.g., "table" - "chair"), 4) contrast (e.g., "dark" - "light"), 5) similarity (e.g., "mountain" - "hill"), 6) part-whole (e.g., "soldier" - "army"), 7) whole-part (e.g., "music" - "notes"), 8) cause-effect (e.g., "sickness" - "death"), 9) effect-cause (e.g., "sleep" - "tired"), 10) material (e.g., "table" - "wood"), 11) contiguity (e.g., "needle" - "thread"), 12) verb response (e.g., "table" - "eat"), and 13) adjective-noun (e.g., "deep" - "hole").⁷ It should be noted that this classification scheme was primarily intended to compare and contrast child and adult responses. This specific purpose may account for the lack of further differentiation of

⁷ There are 9 additional categories which are not relevant for our stimuli. They are: 1) participles, 2) noun-adjective, 3) noun-abstract attribute, 4) verb-object, 5) pronouns, 6) sound-similarity, 7) word-compounding, 8) non-specific, and 9) miscellaneous.

noun/verb responses (type 12)⁸ and adjective/noun responses (type 13).

According to this classification scheme, noun/noun stimuli appear to involve a greater variety of relationships than do other stimulus pairs. For example, the adjective/adjective stimuli in our study are of only 2 types, coordinate (e.g., "sour" - "bitter", "cold" - "chilly") accounting for 10 of the 40 stimulus pairs, and contrast (e.g., "bad" - "good", "deep" - "shallow") accounting for 30 of the stimulus pairs. However, there are 9 types of relationships in our noun/noun stimuli (2 - superordination; 2 - subordination; 18 - coordination; 2 - contrast; 4 - similarity; 3 - part-whole; 5 - whole-part; 1 - cause-effect; 3 - contiguity). There are two potential implications. First, it is possible that different relationships are associated with different degrees of priming (e.g., superordination associations may elicit greater amounts of priming than part-whole associations). Second, it is possible that the number of relationship types in the stimulus list affects the amount of priming (e.g.,

⁸ Other classification schemes which have been primarily developed to describe syntactic relations in language contexts, have further differentiated noun/verb associations. For example, relationships between nouns and verbs can be characterized as: the instrument of the action, the object of the action, the patient of the action, the recipient of the action, the location of the action, and the time of the action.

superordination associations may elicit one level of priming when they are presented alone, a slightly lower level of priming when they are mixed with one or two other association types and a much lower level of priming when they are mixed with multiple association types). This second alternative could also explain why priming appeared to be larger in the blocked stimulus sets in the Methodological Experiments. As mentioned above, in the literature, the segregation of noun/noun stimuli generally occurs when the experimenter is examining categorical relations and as a result, those stimuli would be primarily of the superordination, subordination, coordination, contrast and similarity types (e.g., Lupker [1984] who specifically examined category member, in contrast to subordinate or superordinate associations, used 5 coordinate, 15 contrast and 5 similarity associations out of 30 stimuli). This more limited distribution of relations and the use of specific types of associations could account for the larger priming seen in some of the studies in the literature. These issues could be examined by comparing the amount of priming elicited by superordination, subordination, coordination, contrast and similarity associations when they are blocked and when they are mixed.

The second, third and fourth behavioral hypotheses all involved the syntagmatic/paradigmatic distinction. The two

types of paradigmatic stimuli (i.e., noun/noun and adjective/adjective) were predicted to elicit similar priming results, as were the two types of syntagmatic stimuli (i.e., noun/verb and adjective/noun), and the paradigmatic stimuli were expected to elicit larger priming than the syntagmatic stimuli. These predictions were not supported. There was an interaction of association type and grammatical class in almost every comparison. In general, the noun syntagmatic priming was larger than the noun paradigmatic priming but the adjective paradigmatic priming was larger than or equal to the adjective syntagmatic priming (see Figures 7 and 8). In addition, the adjective paradigmatic priming was often larger than the noun paradigmatic priming but the noun syntagmatic priming was usually larger than the adjective syntagmatic priming. An interaction of association type and grammatical class of the prime (i.e., noun/verb verses verb/noun) was also found in Experiment 9. This consistent interaction between grammatical class and association type strongly suggests some independent organization of grammatical classes. This interaction will be discussed at length in the General Discussion section.

Fifth, based on the results of the methodological studies, it was predicted that priming would be inversely related to SOA (i.e., priming would be larger at the shorter

SOAs). The effects of SOA appeared to be different for the visual and auditory paradigms. In the auditory modality, the syntagmatic auditory priming was inversely related to SOA (i.e., noun/verb and adjective/noun priming were larger at the 650 than at the 1150 SOA), but the paradigmatic priming was unaffected by SOA. However, it should be recalled that this is a between-subject comparison. The auditory behavioral portions of these experiments should be replicated in a within-subject paradigm to insure that these differences are not due to subject or situational factors. If these auditory SOA differences can be replicated in a within subject paradigm, the findings would have implications for models of semantic access and auditory word recognition.

In the visual modality priming was not affected by SOA. This finding, although unpredicted, is consistent with three other studies which varied SOA within study (although none of them varied it within subjects) and which had equal percentages of related and unrelated trials (den Heyer, Briand & Dannenbring, 1983; Howard, Shaw, & Heisey, 1986; Canas, 1990).

Sixth, it was methodologically important to demonstrate that the priming patterns were similar across the auditory and visual modalities. Similar patterns would be consistent

with the assumption that there is a modality independent semantic network and it would allow us to compare and combine the auditory and visual literatures. In general, the pattern of priming was the same across the conditions supporting this assumption. Priming was largest for the noun/verb and adjective/adjective conditions and smallest for the noun/noun and adjective/noun conditions. It should be noted that the auditory 1150 SOA condition had a different priming pattern than the other three conditions (noun/noun priming was larger than noun/verb priming). However, as mentioned above, the 1150 SOA auditory results should be checked using a within-subject design before drawing conclusions.

While the pattern of results was similar across modalities, the auditory priming was larger than the visual priming. Holcomb and Neville (1990) also found larger auditory priming. There are two possible explanations for this modality difference: 1) it could be due to the differences in the type and quality of stimuli used in the two paradigms (i.e., acoustic stimuli were used in the auditory paradigm and orthographic stimuli were used in the visual paradigm), or 2) it could be due to differences in the initial processing of these stimuli (i.e., acoustic/phonologic processing for the auditory stimuli and

orthographic processing for the visual stimuli). Each of these explanations will be considered in turn.

The most significant difference between the visual and auditory stimuli, for our discussion, was their "quality". The error rates and the within subject standard deviations were greater for the auditory than for the visual stimulus sets suggesting that the auditory stimuli were harder to identify than the visual stimuli and could be considered "degraded". Research using visual priming paradigms have found larger priming associated with degraded stimuli than with those that are undegraded (Wilding, 1988; Borowsky & Besner, 1991; Holcomb, 1993). This effect can be interpreted as a greater reliance on contextual cues in situations with degraded stimuli. A greater dependence on, and as a result, a greater attention to the semantic aspects of the prime would result in larger amounts of priming. However, there is a problem with this interpretation. The increased priming associated with degrading the target stimuli is generally associated with longer reaction times to related and unrelated targets, but particularly affects the latter. In our study, the larger auditory than visual priming was primarily due to faster auditory reaction times to related stimuli. The unrelated reaction times were relatively unchanged across modality. Nonetheless, the

difference in stimulus quality across the modalities may account for some of the greater auditory priming.

The second explanation suggests that the modality differences in initial sensory processing may be responsible for the larger auditory priming. The associations between acoustic input signals and internal representations are learned substantially earlier than orthographic associations. In addition, the process of teaching orthographic associations is usually mediated by the existing acoustic/phonologic system. One hypothesis, the phonological recoding hypothesis, argues that this mediation is not only important during acquisition, but that in general, "visual representations must be converted into phonological representations before access can occur" (Bradley & Forster, 1987; p. 106). This hypothesis, however, has not been able to explain the findings of semantic paralexias in the oral reading of deep dyslexics (e.g., the misreading of a word such as "horse" as "cow"; Friedman & Albert, 1985) or the access mechanism for ideographic scripts (Bradley & Forster, 1987). As a result, most theories assume that visual stimuli can access the semantic system either through the phonological system after being recoded or through an independent orthographic system (Bradley & Forster, 1987; McCusker, Hillinger & Bias, 1981). Nonetheless, it would not be unreasonable to hypothesize

that the ontologically earlier system could be accessed more rapidly than the developmentally later system resulting in generally faster processing of auditory stimuli. This would be particularly true in situations which required the decoding of each and every stimulus (e.g., reading contextually meaningful material might appear to be more rapid if not every word was processed). This explanation, however, cannot explain why the related targets were associated with faster reaction times in the auditory paradigm but unrelated targets were not.

Our reaction time pattern could be the result of an interaction between processes associated with the stimulus quality and initial decoding. Perhaps, auditory stimuli are associated with faster processing in general. This would result in faster auditory reaction times to both the related and unrelated targets. In addition, perhaps, the quality of the auditory stimuli in our experiment was somewhat degraded. This would result in the slowing of the reaction times to both the related and unrelated targets, but would affect the unrelated targets more significantly. The sum of these two effects could replicate the finding in our studies. Reaction times to related auditory targets were faster than related visual targets because the effects of the degrading only slightly reduced the generally faster auditory processing and the reaction times to the unrelated

auditory and visual targets were approximately equivalent because the effect of the degrading completely wiped out the effect of the auditory access. This explanation is clearly speculative and should be further explored.

E2. Electrophysiological Hypotheses

There were five electrophysiological hypotheses proposed. The first, that 'an N400 effect would be present for all four conditions in both modalities, was found for all conditions, except for the adjective/noun stimuli in the auditory modality. This lack of an N400 effect in the auditory adjective/noun pairs was unexpected given the significant N400 effect in the visual modality for comparable stimuli and the auditory behavioral priming for adjective/noun pairs. However, the finding is consistent with the finding of insignificant behavioral priming for the adjective/noun stimuli at the 1150 SOA in the visual behavioral paradigm. An examination of the individual N400 data suggests that there may be two groups of subjects, one group which has an N400 effect for adjective/noun stimuli and one which does not. Adjective/noun stimuli will be discussed further in the General Discussion Section.

It was also predicted (second and third hypotheses) that the two paradigmatic sets of stimuli would have similar

N400 effects and that the two syntagmatic sets of stimuli would also have similar N400 effects. In the visual paradigm, this hypothesis was supported as there were no statistical differences between the N400 effects elicited by any of the stimulus sets. However, in the auditory modality, the interaction of association type and grammatical class approached significance, primarily due to the absence of an N400 effect in the adjective/noun condition. A comparison of the N400 effects in the paradigmatic and syntagmatic conditions, found that the noun syntagmatic stimuli elicited a larger N400 effect than the adjective syntagmatic stimuli but that there was no statistical difference between the N400 effects in the noun and adjective paradigmatic conditions. In addition to the comparisons described above, the noun syntagmatic stimuli elicited a larger N400 effect than the noun paradigmatic stimuli and the adjective paradigmatic stimuli elicited a larger N400 effect than the adjective syntagmatic stimuli. It should be noted that this pattern of results was almost identical to that seen in the behavioral priming data. As mentioned above, this interaction will be discussed further in the General Discussion Section.

Given the strong, consistent interaction pattern found in the behavioral priming data, it is surprising that there was no interaction of association type and grammatical class

in the visual N400-effect data and only a marginal interaction in the auditory N400-effect data. There are two possible explanations for this difference between the N400-effect results and the priming results. First, it is possible that priming and N400 effects may be elicited by different aspects or components of semantic processing. Holcomb (1993) has argued this, based upon his finding that the N400 effect was unaffected by stimulus degradation when priming was affected. Brown and Hagoort (1993) have also argued that priming and N400 effects are associated with different components of semantic processing based on their finding of a small but significant priming effect and no N400 effect in a masked priming paradigm. However, none of these findings have demonstrated a double dissociation, so the second possible explanation is that the N400 measure is simply too variable to allow for the resolution of small differences using the current experimental paradigms (e.g., the variability could be reduced by significantly increasing the number of trials).

Fourth, it was methodologically important to demonstrate that the visual and auditory N400 effect patterns were comparable. This was supported by the absence of significant differences between the two modalities in the size of the N400 effect. It should be noted that Holcomb and Neville (1990) found larger N400 effects in the auditory

than in the visual modality but their difference was based on the mean amplitude for a 200-700 msec window. This is a much larger window than is generally used to examine the N400 effect and includes not only the area of the N400 but also the area of the P300. There does appear to be a P300 modality difference and this at least partially explains their modality difference in the 200-700 msec window (see Figure 5). Perhaps, their N400 modality difference would not have been significant had they used the 300-500 msec window which they had used to compare the related and unrelated N400s. The other difference between our auditory and visual results, which should be mentioned, is the significant adjective/noun N400 effect in the visual modality and the absence of an effect in the auditory modality.

The fifth, and final hypothesis was that there would be differences in the topographic distributions of the N400 effects associated with syntagmatic and paradigmatic stimuli. However, no differences were found in either modality. As discussed above, this does not necessarily imply that there are no differences in the underlying brain generators, only that the spatial summations measured at the scalp were not differentiable.

In summary, the results of both the behavioral and electrophysiological experiments have demonstrated noun and adjective, paradigmatic and syntagmatic, semantic associations. In addition, the behavioral paradigm was sensitive to an interaction between the grammatical class of the prime and the association type. Priming was generally larger in the noun syntagmatic and the adjective paradigmatic conditions than in the noun paradigmatic and the adjective syntagmatic conditions. Furthermore, neither measure of semantic relatedness, priming or N400 effects, appeared to be sensitive to modality which is consistent with the assumption of a modality free central semantic system.

IV. GENERAL DISCUSSION

The experiments reported here have shown that the syntagmatic associations which predominate in childhood are still present in adulthood. In addition, as hypothesized, adults evidence paradigmatic associations. These findings are consistent with a model of semantic development which postulates that newly acquired concepts and associations are added to the already existing network. If this is so, then what is the nature of the relationship between paradigmatic and syntagmatic associations in adulthood? Based on the adult word association data it was hypothesized that

experimental paradigms thought to measure semantic associations, would indicate that paradigmatically related pairs were more strongly associated than syntagmatic pairs. This was hypothesized to be true regardless of the grammatical class of the words in the pairs. However, an interaction of grammatical class and association type was found. This issue will be examined below.

A. The Grammatical Class/Association Type Interactions

As mentioned above, it was hypothesized that regardless of the grammatical class of the words, paradigmatically related pairs would be more strongly related than syntagmatically related pairs. This was hypothesized, despite the inherent interactions of word class and association type in childhood caused by the different ages at which the syntagmatic/paradigmatic shifts takes place for different parts of speech (see Table 1; Entwisle, 1966). It was assumed that once the shift had occurred, paradigmatic processing would be stable across grammatical class. Inherent in this assumption was the belief that there is a single semantic organization, which includes all parts of speech. Regardless of the semantic organization, information about the grammatical classes of words must be available in some form, because it is critical for the production and comprehension of language and can be elicited

by a wide variety of experimental paradigms. The data from this series of experiments indicates, in addition, that information about grammatical class affects semantic processing. One model has addressed this issue by postulating different semantic organizing principles for different parts of speech.⁹

Miller and Fellbaum (1991)¹⁰ have argued that:

no single set of semantic relations or organizational structure is adequate for the entire lexicon: nouns, adjectives, and verbs each have their own semantic relations and their own

⁹ Alternatively, it has been argued that the lexicon is organized by grammatical class. The lexicon has been traditionally defined as the memory for the orthographic and phonological representations of words. This view has developed out of the aphasia literature, specifically as an explanation for the dissociation between Broca's and Wernicke's aphasic's abilities to produce nouns and verbs. Broca's patients have difficulty producing verbs and Wernicke's aphasics have difficulty producing nouns (Miceli, Silveri, Villa & Caramazza, 1984; William & Canter, 1987; Caramazza & Hillis, 1991). These aphasia-specific deficits are interpreted as "a disruption to a subcomponent of the lexicon" (Miceli et al., p 217). These models are not considered further because they present no specific proposal regarding the form of the organization and, as a result, make no predictions regarding the form of the interaction found in the present experiments.

¹⁰ Miller and Fellbaum (1991) presented organizational structures for nouns, adjectives and verbs. The verb structures are not discussed here since there were no stimuli in the present study with verb primes. Huttenlocher and Lui (1979) have also suggested a semantic organization for verbs.

organization determined by the role they must play in the construction of linguistic messages (p. 197).

Before discussing these different organizations, it should be recalled that Miller's general model of semantic organization is a cross between network and feature models (Miller & Johnson-Laird, 1976; discussed above in the section on Adult Models of Semantic Organization). He views concepts as lists of features which include properties such as parts, attributes and functions, as well as the concept's superordinates (e.g., the features of apple would include red, good to eat, fruit, and food). So, although concepts are not "connected" in a network fashion, they are cross-referenced. According to Miller and Fellbaum, this cross-referencing for nouns creates hierarchically organized semantic structures with specific properties associated with each concept. This structure is reminiscent of the Collins and Quillian (1969) model (discussed in the section on Adult Models of Semantic Organization), except that the concepts are not directly connected. Such a model would predict that the strongest associates for nouns would be superordinates and characteristic properties (these could be nouns, verbs or adjectives).

The organization of adjectives is quite different. A distinction must be made between two types of adjectives: predicates and non-predicates. A predicative adjective can be used as the predicate in a sentence (e.g., "sunny day" can be rephrased as "the day is sunny"), but a non-predicative adjective cannot (e.g., "top floor" cannot be rephrased, "the floor is top" does not make sense). Non-predicative adjectives are similar to nouns in a number of ways and as a result, are thought to be organized in a similar manner. Non-predicative adjectives will not be considered further as they only account for 3 of the 40 stimuli used in the present experiments. Predicate adjectives (hereafter referred to simply as adjectives), according to Miller and Fellbaum (also see Gross, Fischer, & Miller, 1989), are thought to be organized around bipolar antonym pairs (e.g., "heavy" - "light"). This assumption makes ecological sense in that the "function of predicate adjectives is to express values of attributes, and ... most attributes are bipolar" (p.210). However, some adjectives do not have natural or direct antonyms (e.g., "weightless", "ponderous"). These adjectives are generally synonyms or near synonyms of bipolar adjectives and are associated with that bipolar adjective creating a cluster of synonyms (see Figure 12). This organization would predict that direct antonym pairs and synonyms are the strongest associates. The next level of association would be between an adjective

and a synonym of its antonym (e.g., "dry" - "moist", called indirect antonyms by Miller and Fellbaum). The data from a study by Gross, Fischer and Miller (1989) have supported this by demonstrating that direct antonyms are responded to more quickly than indirect antonyms in a semantic decision task. This model does not predict strong adjective/noun associations in adults. It assumes "that the interactions between adjectives and nouns are not prestored, but are computed as needed by some on-line interpretive process" (p. 214).

WET	DRY
(antonym) - DRY	(antonym) - WET
(synonym) - MOIST	(synonym) - PARCHED
DRENCHED	ARID
SATURATED	DESICCATED
SOAKED	RAINGLESS
SOGGY	WATERPROOF
WATERLOGGED	WATERTIGHT
DAMP	SEARED
...	...

Figure 12. An example of a bipolar adjective pair in the Miller and Fellbaum (1991) organizational model.

The present data can be compared to the predictions made by the Miller and Fellbaum model. As discussed above, the model's organization of nouns predicts that the strongest associates for nouns would be superordinates (e.g., category labels which are usually nouns) and characteristic properties (which could be nouns, verbs or adjectives). Thus both paradigmatic and syntagmatic associations are predicted. However, it is not clear from the model which of these associations would be stronger, or if they would be of equal strength. The data collected in this study demonstrated that priming was greater for the noun/verb pairs than for the noun/noun pairs and in the visual conditions, that the noun/noun priming was quite small and not statistically significant. This pattern does not seem to be consistent with the model. However, as discussed above, the semantic relationships between the nouns in the noun/noun pairs was variable and only 2 of the 40 pairs were superordinate associations. Twenty-five of the 40 noun/verb pairs were characteristic properties of the prime (e.g., "lion" - "roar") and the rest were properties of the superordinate of the prime (e.g., "eagle" - "fly"). As a result, the experimental stimuli are not well-suited for testing this aspect of the model. A direct test of the model could be done by replicating the present paradigm using nouns and their superordinates (noun/noun stimuli) and their characteristic properties (noun/verb stimuli).

The proposed organization for adjectives predicts that the strongest associates for adjectives would be direct antonyms and synonyms. This model does not predict strong adjective/noun associations. In other words, paradigmatic associations are predicted for adjectives, but syntagmatic relations are not. In general, the data support this prediction. In all conditions, the adjective/adjective priming was greater than or equal to the adjective/noun priming and the adjective/adjective N400 effects were greater than or equal to the adjective/noun N400 effects. In addition, our stimuli are not the "best" for eliciting the largest adjective/adjective priming. Of the 37 predicative adjective/adjective pairs, only 26 were direct antonyms. Six more were synonyms, 3 were indirect antonyms, and 2 were color pairs. On the other hand, our data also suggest that there are adjective/noun associations. These associations may be more visible in childhood, but also need to be accounted for in models of adult semantic organization.

Nelson's model of semantic development (see Introduction for detailed description) can be extended to explain the development of the adult semantic system proposed by Miller and Fellbaum. Nelson proposed that within an event there are slots which allow for variations in the components of an event. The components which can

fill these slots (referred to as slot fillers by Nelson) have generally been characterized as noun objects. However, there is no reason to limit the slots to a specific part of speech. For example, when a child goes to the park they may run, chase a dog, jump, skip, etc.. and an event representation of a trip to the park would have a slot which could be filled by one of these activities. As a result, the slot-filler category would be made up of verbs. In a similar manner, the child could develop slot-filler categories for adjectives. For example, when the child goes to the park it might be either hot or cold outside. These bipolar adjectives would become associated because they could fill the same slot in an event representation. It is probable that bipolar adjectives are used more frequently with young children and that synonyms (or near synonyms) of the bipolar adjectives are not used extensively until the child begins to understand gradations of attributes (e.g., that something that is warm is less hot than something which is hot). Attributes (represented in language by adjectives) can occur in a variety of events associated with a wide variety of different objects. As a result, when they become decontextualized it is reasonable to assume that their association with a specific noun is not particularly strong.

This expanded version of Nelson's model would predict that the paradigmatic or slot filler categories for

different parts of speech would develop independently because of their different functional roles within the event representation. Secondly, as discussed in the section on Nelson's developmental model, her model predicts the development of a categorically organized semantic system for noun concepts. Although these concepts become decontextualized as the child develops, they are often associated with their characteristic properties within an event. As a result, nouns retain their strong syntagmatic associates as they develop strong paradigmatic associates. The extended model can also explain the development of strong paradigmatic antonym associations for adjectives and the relatively weak syntagmatic associations.

B. Summary of Results and Discussion

These experiments were designed to examine the syntagmatic (or sequential) and paradigmatic (or categorical) associations of normal adults. Paradigmatic associations have been extensively studied in adults, but syntagmatic associations have been generally ignored in the adult literature, both in the research and in the models of semantic organization. In addition, it has been hypothesized that the semantic networks of children undergo a reorganization before adulthood which transforms their syntagmatic associations into paradigmatic associations

(Francis, 1972). In contrast, others have argued that syntagmatic processes are critical for adult comprehension and production of language and that adult disfunction in syntagmatic processes can result in a Broca's like aphasia (Luria, 1973; Jakobson, 1971). Nelson (1985, 1986) has presented a developmental model of semantic organization in which syntagmatic event representations provide the base for the acquisition of paradigmatic associations. In her model, both syntagmatic and paradigmatic processes have important roles; paradigmatic organization does not replace syntagmatic organization.

This dissertation hypothesized and demonstrated syntagmatic associations in adults. Two measures were used which are generally thought to reflect semantic organization, behavioral priming and N400 amplitude differences (the N400 effect). Both priming and N400 effects were found for the two types of syntagmatic pairs examined, noun/verb and adjective/noun pairs, demonstrating syntagmatic processing in adults. This finding also extends the traditional behavioral priming and N400 literature by demonstrating that these phenomena are not limited to a particular grammatical class (e.g., nouns) or association type (e.g., noun/noun). Furthermore, the patterns of behavioral priming and N400 effects were similar across the visual and auditory modalities which is consistent with the

assumption of a modality free central semantic system and allows for the generalization of findings across the modalities.

The second issue addressed in this dissertation was the relationship between syntagmatic and paradigmatic processes. It was hypothesized that paradigmatic associations would be stronger than syntagmatic associations, given the adult paradigmatic response bias on word-association tasks. This was not found. In the behavioral priming experiments, an interaction of association type and grammatical class was consistently found and in the electrophysiological experiment, no effect of either factor was found.

The difference in the behavioral priming and N400 measures can be interpreted in two ways: 1) the measures may be sensitive to different aspects of semantic processing or 2) given the typical number of experimental trials, the electrophysiological data might be too variable to differentiate small differences between conditions. The data presented here are not sufficient to discriminate between these alternatives.

The association-type by grammatical-class interaction in the priming data has been hypothesized to reflect separate semantic structures for different grammatical

classes, as suggested by Miller and Fellbaum (1991). This hypothesis, however, could not be fully tested with these data because the relationships between the noun/noun stimuli did not conform to the noun organizational structures postulated by Miller and Fellbaum. This hypothesis is preliminary and should be further explored.

C. Future Studies

The general discussion above suggests a number of important potential directions for future research. Some of these directions, particularly a more systematic exploration of the types of noun/noun associations and a within subject replication of the auditory priming study, have been described in the preceding discussion. A number of others will be presented here.

First, the original presentation of the Nelson model, and the extension suggested above, make specific predictions about the developmental organizational changes underlying the syntagmatic/paradigmatic shift. For example, preschool children would be expected to have larger adjective/noun priming than adjective/adjective priming. It would be important to examine these changes, preferably within subjects, to test and refine the Nelson model. It would also be important to determine if the progression from

syntagmatic to paradigmatic organization occurs independently for each word class or if there are developmental interactions. These issues should be explored using an auditory priming paradigm and paradigmatic and syntagmatic stimuli from different parts of speech.

Second, an examination of the individual N400 effect data suggests that there may be individual variations in the underlying semantic networks. It would be important to explore this further to determine if the interaction results reflect a single prototypic model with expected individual variation or if results represent an average of two or more different types of organizations or continuums of organizations which different groups of individuals possess. It is possible that there is a continuum determined by the percentage of syntagmatic and paradigmatic associations. The word association literature suggests that one of the important variables which might be correlated with an organizational continuum, would be vocabulary.

Third, it would be important to examine the developmental progression in a group which appears to be intellectually intact (defined as an average or better nonverbal IQ) but who have language difficulties (i.e., developmentally language disordered children). The Nelson model would not suggest any differences early in development

assuming that these children can adequately represent event sequences and slot fillers. However, difficulties would be expected in higher level taxonomic categories and paradigmatic adjective associations (particularly indirect antonyms) due to the hypothesized involvement of language in the acquisition of these associations (see Introduction for additional details). It would be important to determine if the semantic organizations in these children were developmentally delayed or developmentally deviant.

Fourth, it would be important to determine if bilinguals who are now fluent in English but who learned a different language first, exhibit similar priming patterns. If the lexicon is language specific and the semantic system is language independent then bilinguals should show similar patterns to English monolingual. However, if the semantic system or parts of the semantic system are language dependent, different patterns might be exhibited. It is of course also possible that the semantic system is language independent but that first language learned plays a significant role in the organization of that system and that there are language specific organization characteristics. This could also be examine by comparing monolinguals and bilinguals.

APPENDIX A - Stimuli for Experiments 1 - 5

RELATED NOUN/NOUN PAIRS

- * - strongly associated stimuli, stimuli with relatedness ratings in the norming study of 1/2 SD above the mean
- X - excluded stimuli, stimuli with relatedness ratings in the norming study of greater than 2 SD from the mean

1. BUTTERFLY-MOTH
2. DINNER - SUPPER *
3. CHILD - BABY
4. CITIZEN - PERSON
5. DOCTOR - NURSE
6. OCEAN - SEA *
7. FOOT - SHOE *
8. FRUIT - APPLE *
9. HAND - ARM
10. HEAD - HAIR *
11. HOUSE - HOME *
12. MOON - STARS
13. VALLEY - MOUNTAIN
14. MUSIC - SONG *
15. PRIEST - CHURCH *
16. RELIGION - GOD *
17. SHEEP - WOOL
18. SCISSORS - PAPER
19. SOLDIER - ARMY *
20. SPIDER - INSECT *
21. STREET - AVENUE
22. BIBLE - BOOK
23. MORNING - EVENING
24. STOMACH - FOOD
25. BUTTER - MARGARINE
26. BUSINESS - MONEY
27. BEER - PRETZELS X
28. STREAM - RIVER
29. TRUMPET - HORN
30. BOMB - WAR *
31. FLOWER - ROSE *
32. CITY - TOWN
33. SQUARE - CIRCLE
34. PEOPLE - CROWD
35. CAR - TRUCK
36. AUTHOR - WRITER *
37. CABBAGE - LETTUCE
38. JUSTICE - LAW *
39. EARTH - DIRT
40. SOFA - COUCH *

RELATED NOUN/VERB PAIRS

1. CHAIR - SIT	*
2. BED - SLEEP	*
3. LION - ROAR	
4. STOVE - COOK	
5. THIEF - STEAL	*
6. WHISKEY - DRINK	
7. SKILLET - FRY	
8. WHISKER - SHAVE	X
9. OVEN - BAKE	*
10. TOURIST - TRAVEL	*
11. LETTER - WRITE	*
12. CANARY - SING	
13. EAR - HEAR	
14. NOSE - SMELL	*
15. DOOR - OPEN	
16. WASP - STING	
17. BUGLE - BLOW	X
18. PEPPER - SNEEZE	
19. ONION - CRY	
20. GUN - SHOOT	*
21. KNIFE - CUT	*
22. BALL - BOUNCE	
23. PLUMBER - FIX	
24. PILOT - FLY	
25. HORSE - RIDE	
26. DOG - BARK	
27. SHARK - BITE	
28. BEACH - SWIM	*
29. TOBACCO - SMOKE	*
30. CHEESE - EAT	
31. HAMMER - HIT	
32. MIND - THINK	*
33. NEEDLE - SEW	*
34. TENNIS - PLAY	
35. COAT - WEAR	
36. CLIFF - FALL	
37. ANT - CRAWL	X
38. BEE - BUZZ	
39. GUITAR - STRUM	X
40. PROFESSOR - TEACH	*

APPENDIX B - Visual Stimuli for Experiments 6 - 9**NOUN/NOUN/VERB LIST 1**

1. FRUIT-APPLE-EAT	IPPLE-EAM
2. NEEDLE-THREAD-SEW	THREAM-SEF
3. EAGLE-BIRD-FLY	ZIRD-GLY
4. BOOK-MAGAZINE-READ	MARAZINE-REAJ
5. SOLDIER-ARMY-FIGHT	ARSY-DIGHT
6. BED-PILLOW-SLEEP	CILLOW-KLEEP
7. HORSE-COW-RIDE	JOW-KIDE
8. DOOR-WINDOW-OPEN	WINHOW-OTEN
9. NUMBER-LETTER-COUNT	CETTER-WOUNT
10. NOSE-MOUTH-SMELL	GOUTH-SMULL
11. SHARK-FISH-BITE	BISH-BIVE
12. BEE-HONEY-BUZZ	TONEY-BEZZ
13. TRUMPET-HORN-BLOW	SORN-BLOG
14. PENCIL-PEN-WRITE	FEN-WRETE
15. MAN-WOMAN-WORK	WOHAN-GORK
16. DOCTOR-NURSE-HEAL	FURSE-QEAL
17. BALL-BAT-THROW	BAF-THROP
18. HAIR-HEAD-COMB	HEAG-LOMB
19. FLOWER-ROSE-GROW	ROKE-GROM
20. MOUNTAIN-HILL-CLIMB	HILU-CLIMO

NOUN/NOUN/VERB LIST 2

1. CHAIR-TABLE-SIT	RABLE-SIJ
2. THIEF-ROBBER-STEAL	RABBER-STEAC
3. BATH-SOAP-WASH	YOAP-TASH
4. HAMMER-NAIL-HIT	LAIL-HIB
5. LION-TIGER-ROAR	SIGER-HOAR
6. TOBACCO-CIGARETTE-SMOKE	CINARETTE-SMOFE
7. DOG-CAT-BARK	DAT-TARK
8. GUN-BULLET-SHOOT	BULLEM-SLOOT
9. MUSIC-SONG-SING	VONG-HING
10. BEACH-SAND-SWIM	SANO-QWIM
11. BABY-CHILD-CRY	CRILD-CLY
12. BOMB-WAR-EXPLODE	HAR-EXPLOME
13. MIND-BRAIN-THINK	FRAIN-SHINK
14. BUG-INSECT-CRAWL	INLECT-CRAWA
15. COAT-HAT-WEAR	JAT-WEAB
16. PIANO-GUITAR-PLAY	GUILAR-PLAM
17. ARM-LEG-BREAK	GEG-TREAK
18. STOVE-OVEN-COOK	OJEN-VOOK
19. SHOE-SOCK-TIE	BOCK-CIE
20. CHURCH-TEMPLE-PRAY	REMPLE-PRAS

ADJECTIVE/ADJECTIVE/NOUN LIST 1

1. DARK-LIGHT-NIGHT	LIGHO-NIRHT
2. EASY-HARD-TEST	SARD-TESO
3. DEEP-SHALLOW-WATER	SHALLOR-WASER
4. BAD-GOOD-BOY	GEOD-BOF
5. BEAUTIFUL-HANDSOME-GIRL	DANDSOME-BIRL
6. BLUE-RED-SKY	REW-SKO
7. TALL-SHORT-BUILDING	SHORY-RUILDING
8. SHARP-DULL-TONGUE	DUJL-TINGUE
9. TOP-BOTTOM-FLOOR	BOTTOR-FLOOJ
10. OLD-YOUNG-LADY	BOUNG-LAGY
11. WICKED-MEAN-PERSON	HEAN-PERLON
12. BRAVE-SCARED-HERO	SMARED-HELO
13. BACK-FRONT-YARD	CRONT-NARD
14. RICH-POOR-PEOPLE	PEOR-MEOPLE
15. NARROW-WIDE-STREET	WIGE-SCREET
16. MARRIED-SINGLE-COUPLE	SINTLE-MOUPLE
17. MILD-HARSH-DETERGENT	VARSH-WETERGENT
18. UGLY-PRETTY-DRESS	PRETTU-DROSS
19. HOT-WARM-FIRE	WARB-FIDE
20. GREEN-YELLOW-GRASS	DELOW-GRISS

ADJECTIVE/ADJECTIVE/NOUN LIST 2

1. SOFT-FLUFFY-COTTON	FLUFFU-COTTOT
2. SMOOTH-ROUGH-SILK	ROUZH-CILK
3. COLD-CHILLY-WINTER	CHILLU-WINTEW
4. FAST-SLOW-CAR	SLON-CAL
5. HUNGRY-THIRSTY-FOOD	KHIRSTY-COOD
6. SOUR-BITTER-LEMON	BITTEK-LEMOD
7. WHITE-BLACK-SNOW	KLACK-SKOW
8. ROUND-SQUARE-CIRCLE	SQUAJE-BIRCLE
9. WILD-TAME-ANIMAL	TAMA-AGIMAL
10. SAD-HAPPY-FACE	WAPPY-FUCE
11. NEAT-MESSY-ROOM	PESSY-ROOQ
12. SMALL-LARGE-PARTY	VARGE-PARPY
13. FIRST-LAST-PRIZE	TAST-PRIBE
14. BRIGHT-SMART-SUN	SMARY-JUN
15. BIG-LITTLE-PROBLEM	BITTLE-SROBLEM
16. LEFT-RIGHT-TURN	GIGHT-HURN
17. CLEAN-DIRTY-HOUSE	DIRLY-BOUSE
18. HIGH-LOW-LADDER	LOK-LADDEM
19. RAINY-WINDY-DAY	RINDY-DAR
20. EMPTY-FULL-GLASS	RULL-GLASU

APPENDIX C - Auditory Stimuli for Experiment 6**NOUN/NOUN/VERB**

1. FRUIT-APPLE-EAT	IPPLE-EAM
2. SOLDIER-ARMY-FIGHT	ARSY-DIGHT
3. EAGLE-BIRD-FLY	ZIRD-GLY
4. BATH-SOAP-WASH	YOAP-TASH
5. HAMMER-NAIL-HIT	LAIL-HIB
6. LION-TIGER-ROAR	SIGER-HOAR
7. BED-PILLOW-SLEEP	CILLOW-KLEEP
8. TOBACCO-CIGARETTE-SMOKE	CINARETTE-SMOFE
9. DOG-CAT-BARK	DAT-TARK
10. DOOR-WINDOW-OPEN	WINHOW-OTEN
11. NUMBER-LETTER-COUNT	CETTER-WOUNT
12. MUSIC-SONG-SING	VONG-HING
13. TRUMPET-HORN-BLOW	SORN-BLOG
14. MIND-BRAIN-THINK	FRAIN-SHINK
15. PENCIL-PEN-WRITE	FEN-WRETE
16. CHURCH-TEMPLE-PRAY	REMPLE-PRAS
17. PIANO-GUITAR-PLAY	GUILAR-PRAS
18. ARM-LEG-BREAK	GEG-CREAK
19. MAN-WOMAN-WORK	WOHAN-GORK
20. BABY-CHILD-CRY	CHILM-CLY
21. GUN-BULLET-SHOOT	BULLEM-GHOOT
22. MOUNTAIN-HILL-CLIMB	HILA-CLIMO
23. BEACH-SAND-SWIM	SANI-QWIM
24. HAIR-HEAD-COMB	JEAD-LOMB

ADJECTIVE/ADJECTIVE/NOUN

1. DARK-LIGHT-NIGHT	LIGHO-NIRHT
2. EASY-HARD-TEST	SARD-TESO
3. COLD-CHILLY-WINTER	CHILLU-WINTEW
4. WHITE-BLACK-SNOW	KLACK-SKOW
5. BEAUTIFUL-HANDSOME-GIRL	DANDSOME-BIRL
6. BLUE-RED-SKY	REW-SKO
7. HUNGRY-THIRSTY-FOOD	KHIRSTY-COOD
8. GREEN-YELLOW-GRASS	DEELLOW-GRISS
9. TALL-SHORT-BUILDING	SHORY-RUILDING
10. BAD-GOOD-BOY	GEOD-BOF
11. ROUND-SQUARE-CIRCLE	SQUAJE-BIRCLE
12. SHARP-DULL-TONGUE	DUJL-TINGUE
13. CLEAN-DIRTY-HOUSE	DIRLY-BOUSE
14. BRIGHT-SMART-SUN	SMARY-JUN
15. BRAVE-SCARED-HERO	FCARED-HELO
16. SMALL-LARGE-PARTY	VARGE-PARPY
17. OLD-YOUNG-LADY	BOUNG-LAGY
18. MARRIED-SINGLE-COUPLE	SINTLE-MOUPLE
19. LEFT-RIGHT-TURN	GIGHT-HURN
20. HIGH-LOW-LADDER	LOK-LADDEM
21. UGLY-PRETTY-DRESS	PRETTU-DROSS
22. HOT-WARM-FIRE	WARB-FIDE
23. SOUR-BITTER-LEMON	BITTEK-LEMOD
24. SOFT-FLUFFY-COTTON	FLUFFU-COTTOT
25. RAINY-WINDY-DAY	RINDY-DAR
26. DEEP-SHALLOW-WATER	SHALLOR-BATER
27. RICH-POOR-PEOPLE	PEOR-GEOPLE
28. NARROW-WIDE-STREET	WIDA-SCREET
29. BIG-LITTLE-PROBLEM	BITTLE-DROBLEM

APPENDIX D - Presentation Orders for Experiment 6

VISUAL

AUDITORY

N/N-650-LIST 1
 N/N-1150-LIST 2
 N/V-650-LIST 1
 N/V-1150-LIST 2
 A/A-650-LIST 1
 A/A-1150-LIST 2
 A/N-650-LIST 1
 A/N-1150-LIST 2

N/N
 N/V
 A/A
 A/N

N/N-650-LIST 2
 N/N-1150-LIST 1
 N/V-650-LIST 2
 N/V-1150-LIST 1
 A/A-650-LIST 2
 A/A-1150-LIST 1
 A/N-650-LIST 2
 A/N-1150-LIST 1

A/A
 A/N
 N/N
 N/V

N/N-1150-LIST 1
 N/N-650-LIST 2
 N/V-1150-LIST 1
 N/V-650-LIST 2
 A/A-1150-LIST 1
 A/A-650-LIST 2
 A/N-1150-LIST 1
 A/N-650-LIST 2

N/V
 N/N
 A/N
 A/A

N/N-1150-LIST 2
 N/N-650-LIST 1
 N/V-1150-LIST 2
 N/V-650-LIST 1
 A/A-1150-LIST 2
 A/A-650-LIST 1
 A/N-1150-LIST 2
 A/N-650-LIST 1

A/N
 A/A
 N/V
 N/N

A/A-650-LIST 1
 A/A-1150-LIST 2
 N/N-650-LIST 1
 N/N-1150-LIST 2
 A/N-650-LIST 1
 A/N-1150-LIST 2
 N/V-650-LIST 1
 N/V-1150-LIST 2

N/N
 N/V
 A/A
 A/N

A/A-650-LIST 2	A/A
A/A-1150-LIST 1	A/N
N/N-650-LIST 2	N/N
N/N-1150-LIST 1	N/V
A/N-650-LIST 2	
A/N-1150-LIST 1	
N/V-650-LIST 2	
N/V-1150-LIST 1	
A/A-1150-LIST 1	N/V
A/A-650-LIST 2	N/N
N/N-1150-LIST 1	A/N
N/N-650-LIST 2	A/A
A/N-1150-LIST 1	
A/N-650-LIST 2	
N/V-1150-LIST 1	
N/V-650-LIST 2	
A/A-1150-LIST 2	A/N
A/A-650-LIST 1	A/A
N/N-1150-LIST 2	N/V
N/N-650-LIST 1	N/N
A/N-1150-LIST 2	
A/N-650-LIST 1	
N/V-1150-LIST 2	
N/V-650-LIST 1	
N/V-650-LIST 1	N/N
N/V-1150-LIST 2	N/V
A/N-650-LIST 1	A/A
A/N-1150-LIST 2	A/N
N/N-650-LIST 1	
N/N-1150-LIST 2	
A/A-650-LIST 1	
A/A-1150-LIST 2	
N/V-650-LIST 2	A/A
N/V-1150-LIST 1	A/N
A/N-650-LIST 2	N/N
A/N-1150-LIST 1	N/V
N/N-650-LIST 2	
N/N-1150-LIST 1	
A/A-650-LIST 2	
A/A-1150-LIST 1	

N/V-1150-LIST 1	N/V
N/V-650-LIST 2	N/N
A/N-1150-LIST 1	A/N
A/N-650-LIST 2	A/A
N/N-1150-LIST 1	
N/N-650-LIST 2	
A/A-1150-LIST 1	
A/A-650-LIST 2	
N/V-1150-LIST 2	A/N
N/V-650-LIST 1	A/A
A/N-1150-LIST 2	N/V
A/N-650-LIST 1	N/N
N/N-1150-LIST 2	
N/N-650-LIST 1	
A/A-1150-LIST 2	
A/A-650-LIST 1	
A/N-650-LIST 1	N/N
A/N-1150-LIST 2	N/V
A/A-650-LIST 1	A/A
A/A-1150-LIST 2	A/N
N/V-650-LIST 1	
N/V-1150-LIST 2	
N/N-650-LIST 1	
N/N-1150-LIST 2	
A/N-650-LIST 2	A/A
A/N-1150-LIST 1	A/N
A/A-650-LIST 2	N/N
A/A-1150-LIST 1	N/V
N/V-650-LIST 2	
N/V-1150-LIST 1	
N/N-650-LIST 2	
N/N-1150-LIST 1	
A/N-1150-LIST 1	N/V
A/N-650-LIST 2	N/N
A/A-1150-LIST 1	A/N
A/A-650-LIST 2	A/A
N/V-1150-LIST 1	
N/V-650-LIST 2	
N/N-1150-LIST 1	
N/N-650-LIST 2	

A/N-1150-LIST 2	A/N
A/N-650-LIST 1	A/A
A/A-1150-LIST 2	N/V
A/A-650-LIST 1	N/N
N/V-1150-LIST 2	
N/V-650-LIST 1	
N/N-1150-LIST 2	
N/N-650-LIST 1	

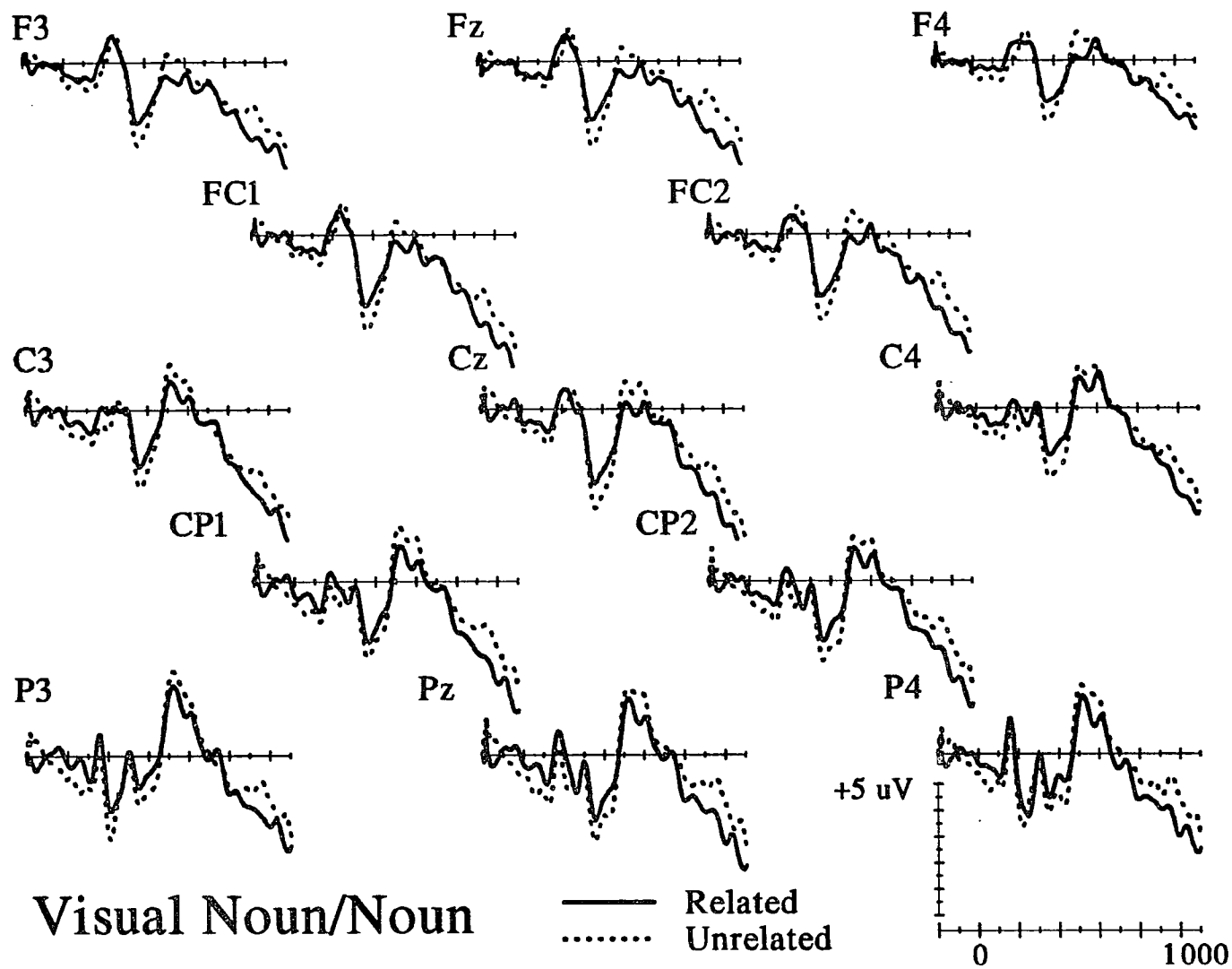
APPENDIX E - Additional Auditory Stimuli for Experiment 7**NOUN/NOUN/VERB**

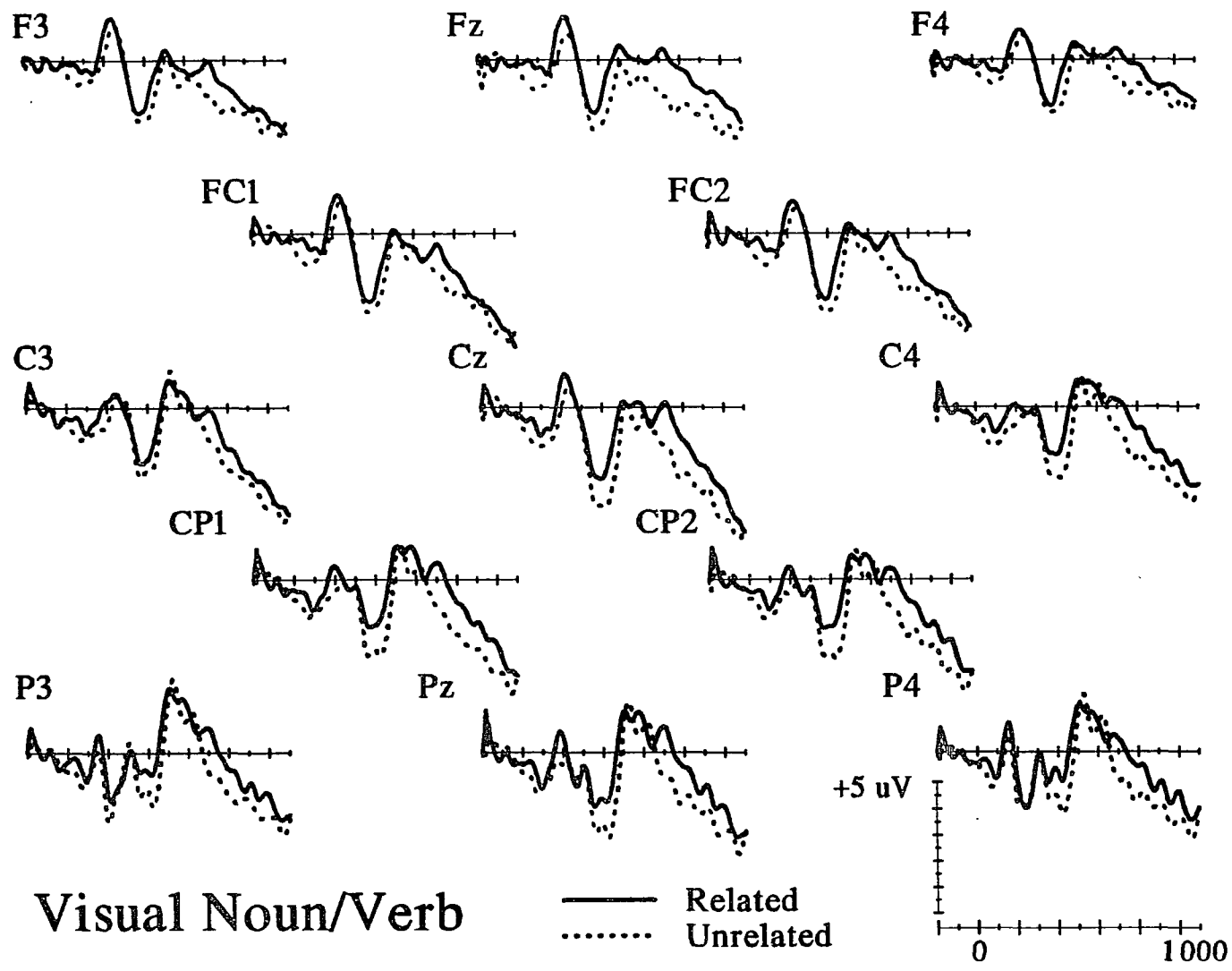
1. SCISSOR-PAPER-CUT
2. PLUMBER-PIPE-FIX
3. PROFESSOR-TEACHER-TEACH
4. PEPPER-SALT-SNEEZE
5. KING-QUEEN-RULE
6. STUDENT-PUPIL-LEARN
7. BLOCKS-TOY-BUILD
8. RABBIT-BUNNY-JUMP
9. CHAIR-TABLE-SIT
10. NEEDLE-THREAD-SEW
11. COAT-HAT-WEAR
12. BOOK-MAGAZINE-READ
13. FLOWER-ROSE-GROW
14. BUG-INSECT-CRAWL
15. BALL-BAT-THROW
16. SHOE-SOCK-TIE

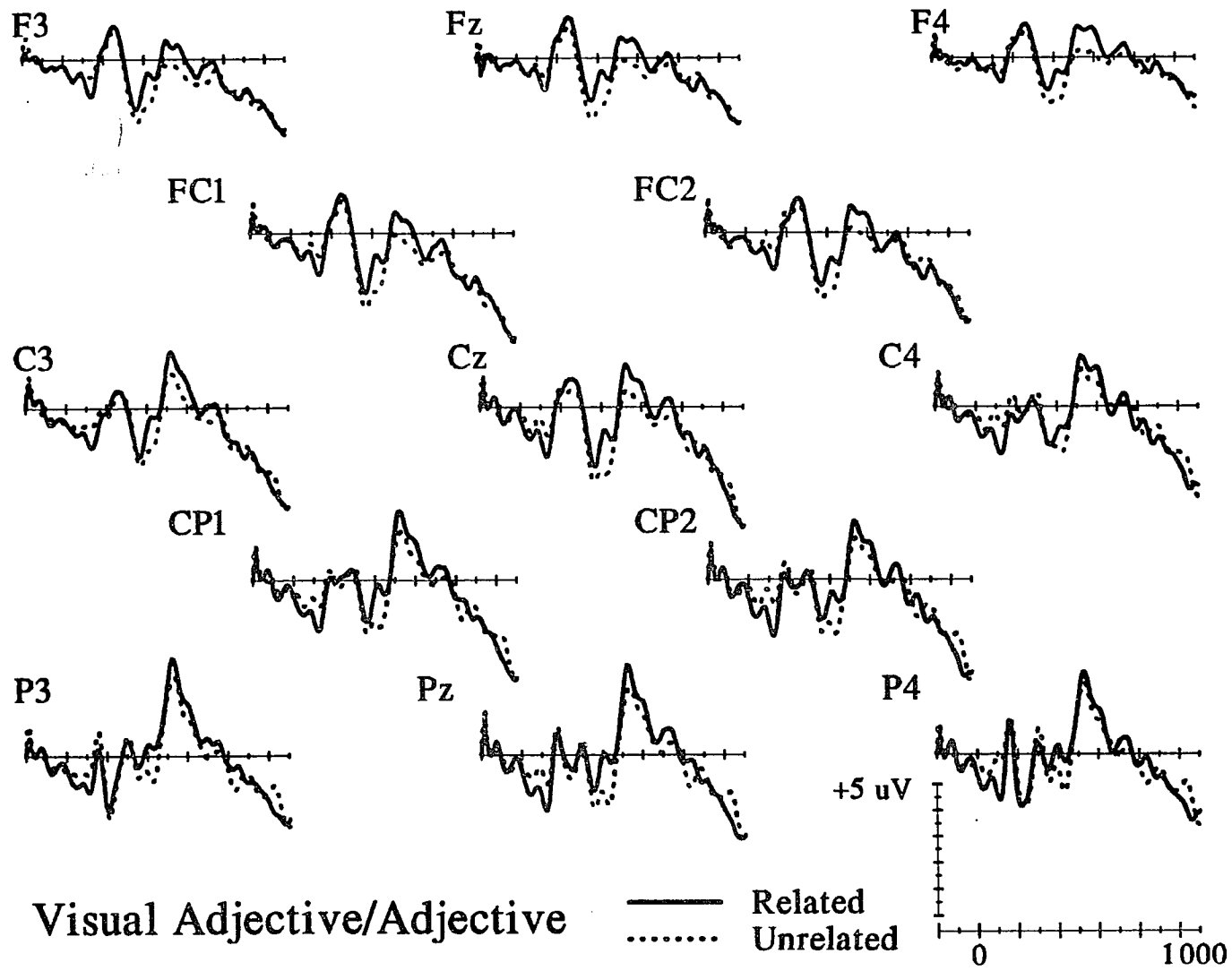
ADJECTIVE/ADJECTIVE/NOUN

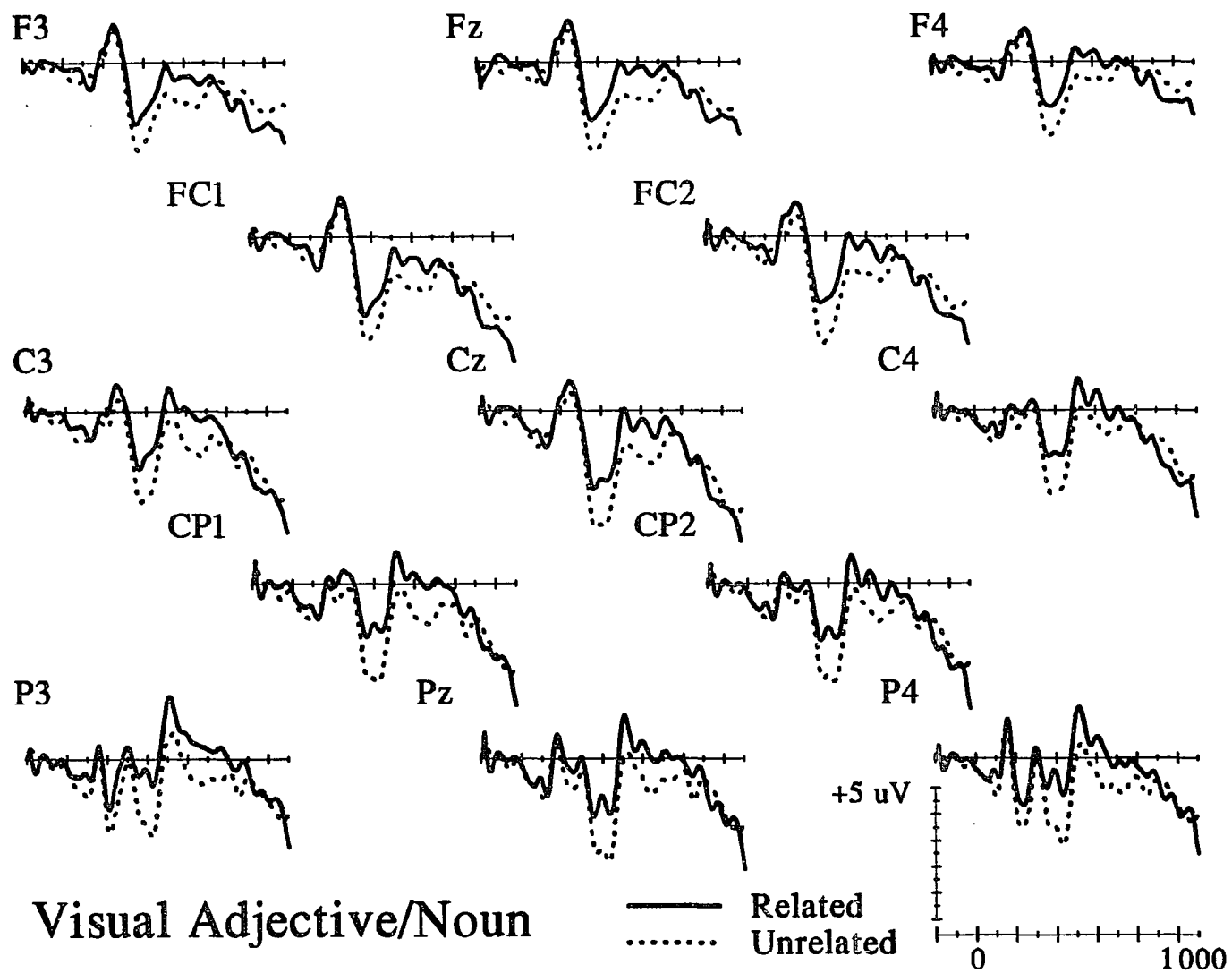
1. SWEET-STICKY-CANDY
2. LOUD-QUIET-NOISE
3. DRY-WET-CLOTHES
4. FRIENDLY-RUDE-SMILE
5. FUNNY-SILLY-CLOWN
6. FRESH-NEW-LETTUCE
7. FAST-SLOW-CAR
8. WILD-TAME-ANIMAL
9. EMPTY-FULL-GLASS
10. BACK-FRONT-YARD
11. MILD-HARSH-DETERGENT

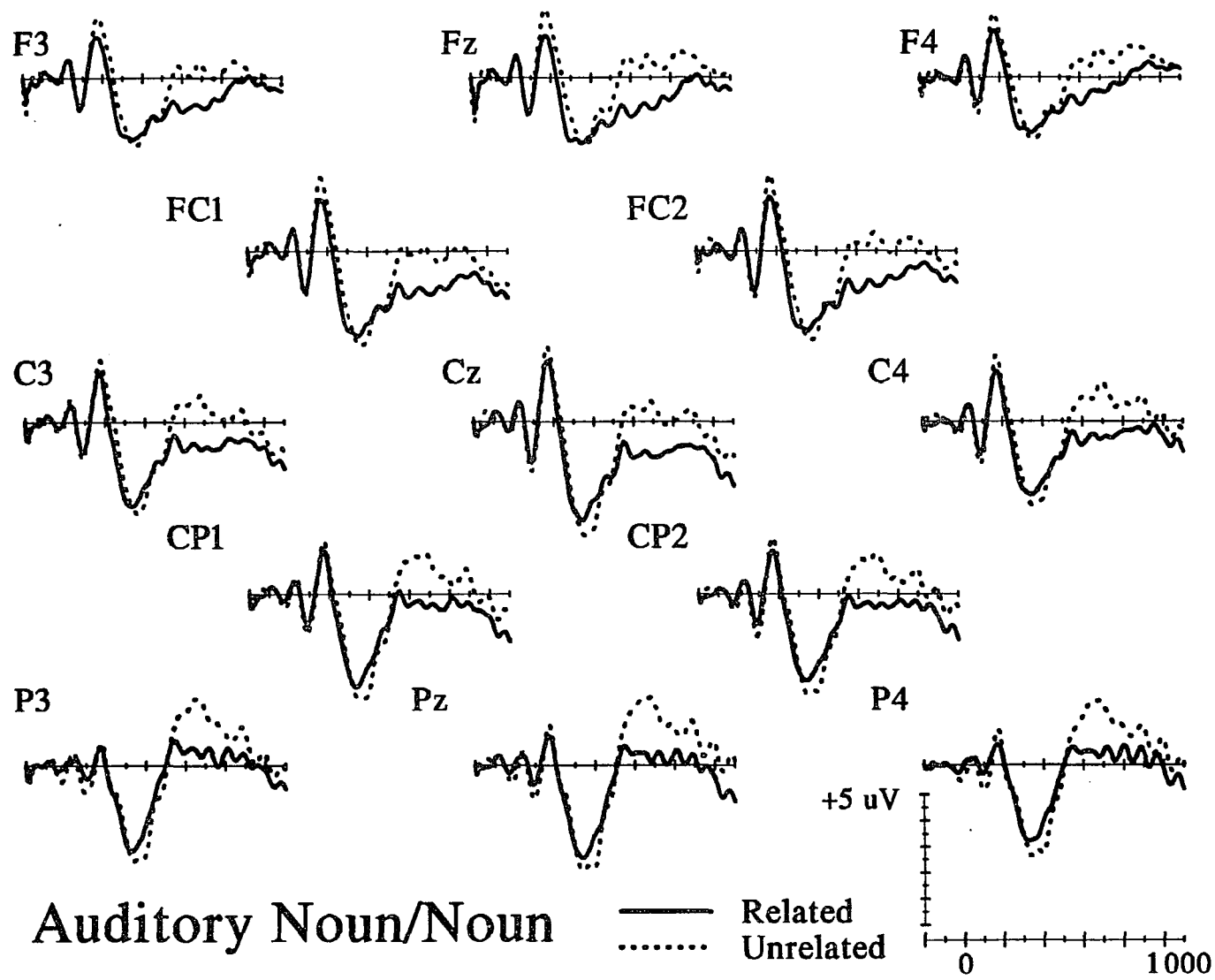
APPENDIX F. Experiment 7. The next eight figures show the grand mean evoked potentials elicited in the four visual and in the four auditory conditions for 13 of the electrodes. The target word was presented at time zero.

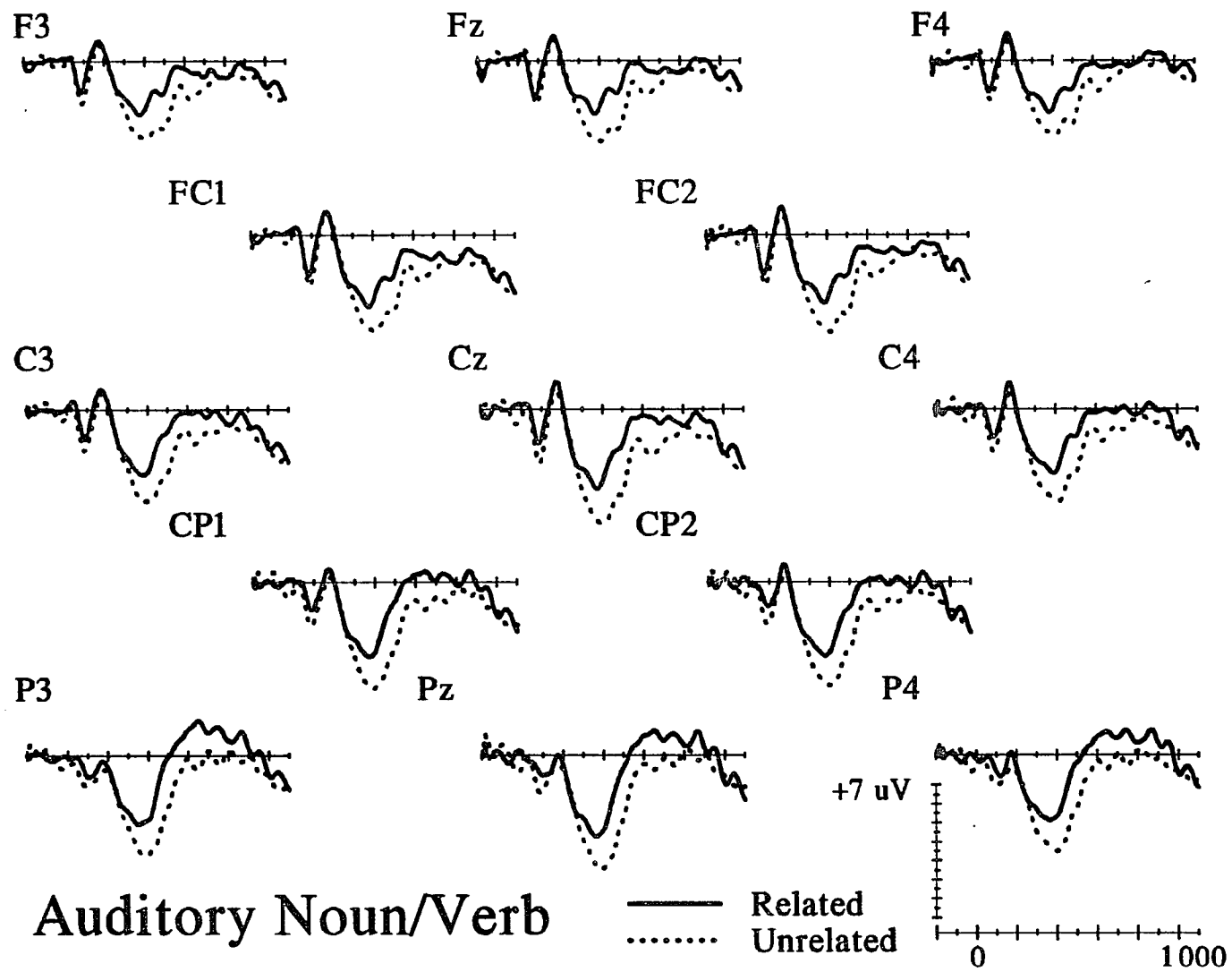


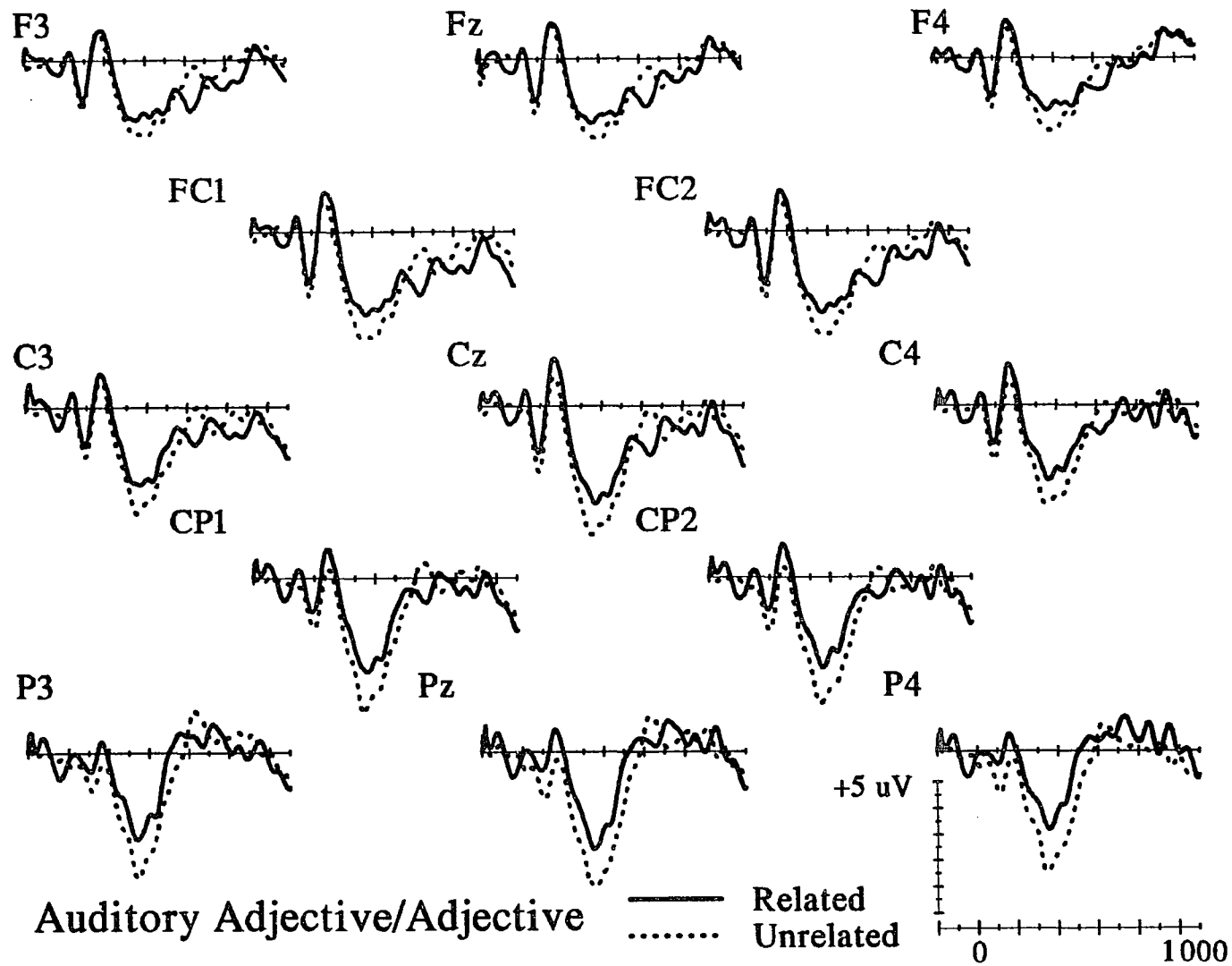


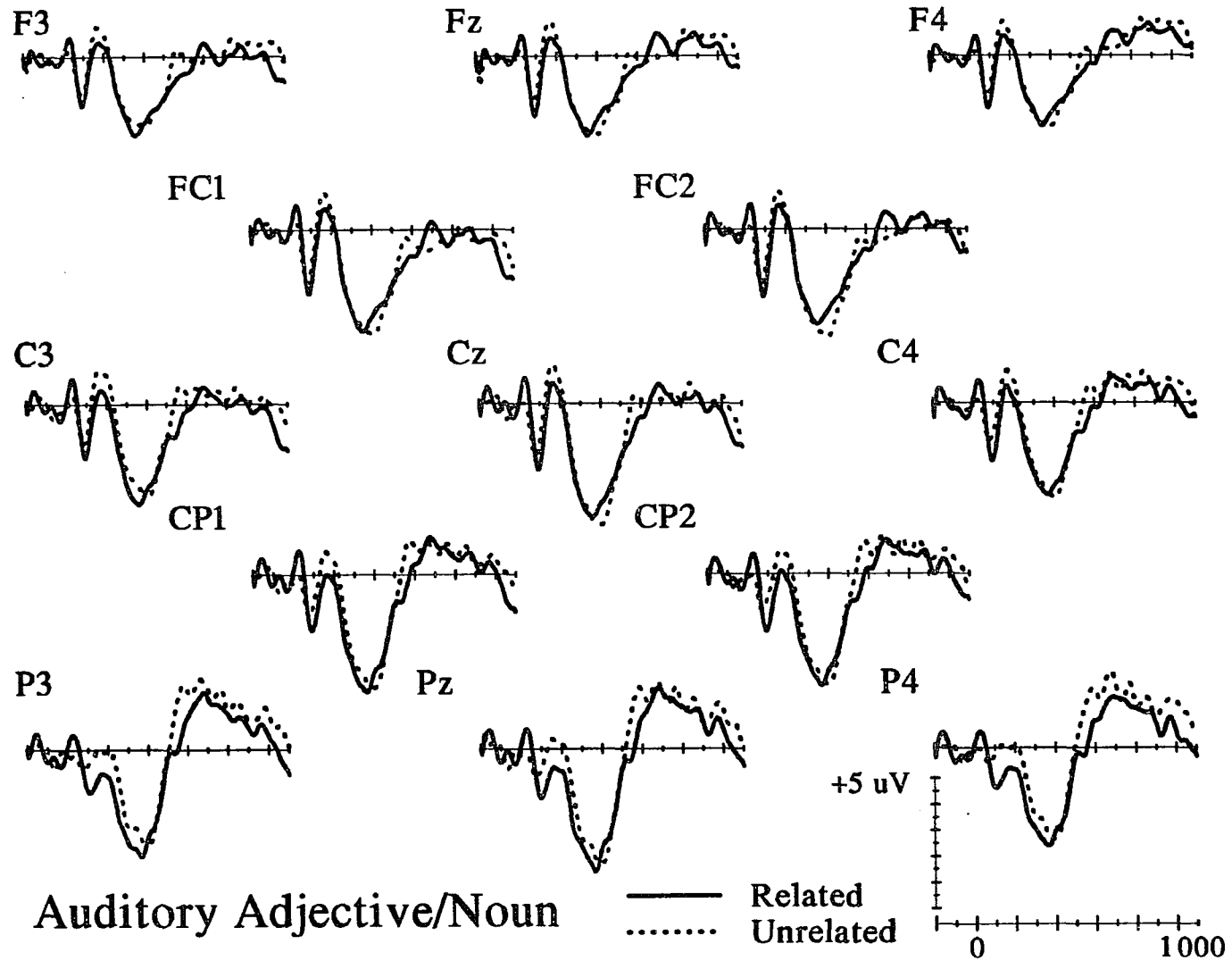












REFERENCES

- Algarabel, S., Pitarque, A., Soler, M. J., Ruiz, J. C., Baixauli, J. M., & Dasi, C. (1987). Effect of prime type on lexical decision time. Perceptual and Motor Skills, 64, 119-125.
- American Electroencephalographic Society (1990). Standard electrode position nomenclature. Bloomfield, CT.
- Anderson, S. W. & Beh, W. (1968). The reorganization of verbal memory in childhood. Journal of Verbal Learning and Verbal Behavior, 77, 1049-1053.
- Baddeley, A. (1988). Cognitive Psychology and Human Memory. Trends in Neuroscience, 11, 176-181.
- Barrett, S. E. & Rugg, M. D. (1990). Event-related potentials and the semantic matching of pictures. Brain and Cognition, 14, 201-212.
- Barrett, S. E., Rugg, M. D., & Perrett, D. I. (1988). Event-related potentials and the matching of familiar and unfamiliar faces. Neuropsychologia, 26, 105-117.
- Becker, C. A. (1980). Semantic context effects in visual word recognition: An analysis of semantic strategies. Memory and Cognition, 8, 493-512.
- Benson, D. F. (1985). Aphasia. In K.M. Heilman and E. Valenstein (Eds.), Clinical neuropsychology (2nd ed.). New York: Oxford University Press.
- Bentin, S., Kutas, M. & Hillyard, S. A. (1993). Electrophysiological evidence for task effects on semantic priming in auditory word processing. Psychophysiology, 30, 161-169.
- Bentin, S., McCarthy, G., & Wood, C. C. (1985). Event-related potentials, lexical decision and semantic priming. Electroencephalography and Clinical Neurophysiology, 60, 343 -355.
- Besner, D., Smith, M. C., MacLeod, C. M. (1990). Visual word recognition: A dissociation of lexical and semantic processing. Journal of Experimental Psychology: Learning, Memory and Cognition, 16, 862-869.
- Besson, M., Fischler, I., Boaz, T. & Raney, G. (1992). Effects of automatic associative activation on explicit and implicit memory tests. Journal of Experimental Psychology: Learning, Memory and Cognition, 18, 89-105.

- Blumstein, S. E. (1988). Linguistic deficits in aphasia. In F. Plum (Ed.), Language, communication, and the brain. New York: Raven Press.
- Blumstein, S. E., Milberg, W., & Shrier, R. (1982). Semantic processing in aphasia: Evidence from an auditory lexical decision task. Brain and Language, 17, 301-315.
- Boddy, J. (1986). Event-related potentials in chronometric analysis of primed word recognition with different stimulus onset asynchronies. Psychophysiology, 23, 232-245.
- Borowsky, R. & Besner, D. (1991). Visual word recognition across orthographies: On the interaction between context and degradation. Journal of Experimental Psychology: Learning, Memory and Cognition, 17, 272-276.
- Bradley, D. C. & Forster, K. I. (1987). A reader's view of listening. Cognition, 25, 103-134.
- Brown, R. & Berko, J. (1960). Word association and the acquisition of grammar. Child Development, 52, 1-14.
- Brown, C. & Hagoort, P. (1993). The processing nature of the N400: Evidence from masked priming. Journal of Cognitive Neuroscience, 5, 34-44.
- Bruner, J. (1986). Actual minds, possible worlds. Cambridge, Mass: Harvard University Press.
- Canas, J. J. (1990). Associative strength effects in the lexical decision task. The Quarterly Journal of Experimental Psychology, 42, 121-145.
- Caramazza, A., & Berndt, R. S. (1978). Semantic and syntactic processes in aphasia: A review of the literature. Psychological Bulletin, 85, 898-918.
- Caramazza, A. & Hillis, A. E. (1991). Lexical organization of nouns and verbs in the brain. Nature, 349, 788-790.
- Caramazza, A., & Zurif, E. B. (1976). Dissociation of algorithmic and heuristic processes in language comprehension: Evidence from aphasia. Brain and Language, 3, 572-582.
- Chang, T. M. (1986). Semantic memory: Facts and models. Psychological Bulletin, 99, 199-220.
- Chomsky, N. (1965). Aspects of the theory of syntax. Cambridge, Mass.: MIT Press.

- Clark, H. H. (1970) Word associations and linguistic theory. In J. Lyons (Ed.), New horizons in linguistics. Middlesex, England: Penguin Books.
- Cochran, E. L. (1984). Cat. #540 Apple interfacing system. Bayport, NY: Life Science Associates.
- Collins, A. M. & Loftus, E. F. (1975) A spreading activation theory of semantic processing. Psychological Review, 82, 407-428.
- Collins, A. M. & Quillian, M. R. (1969). Retrieval time from semantic memory. Journal of Verbal Learning and Verbal Behavior, 8, 240-247.
- Connolly, J. F., Phillips, N. A., Stewart, S. H., & Brake, W. G. (1992). Event-related potential sensitivity to acoustic and semantic properties of terminal words in sentences. Brain and Language, 43, 1-18.
- Damasio, A. R. (1992). Aphasia. New England Journal of Medicine, 326, 531-539.
- Deacon, D., Breton, F., Ritter, W., & Vaughan, H. G. Jr. (1991). The relationship between N2 and N400: Scalp distribution, stimulus probability, and task relevance. Psychophysiology, 28, 185-200.
- de Groot, A. M. B. (1989). Representational aspects of word imageability and word frequency as assessed through word association. Journal of Experimental Psychology: Learning, Memory and Cognition, 15, 824-845.
- de Groot, A. M. B., Thomassen, A. J. W. M., & Hudson, P. T. W. (1986). Primed-lexical decision: The effect of varying the stimulus-onset asynchrony of prime and target. Acta Psychologica, 61, 17-36.
- den Heyer, K., Briand, K., & Dannenbring, G. I. (1983). Strategic factors in a lexical-decision task: Evidence for automatic and attention-driven processes. Memory and Cognition, 11, 374-381.
- Denney, N. W. (1974). Evidence for developmental changes in categorization criteria for children and adults. Human Development, 17, 41-53.
- de Saussure, G. (1959). Course in general linguistics. New York: McGraw-Hill. (Original work published in 1915).
- Entwistle, D. R. (1966). Word associations of young children. Baltimore, MD: Johns Hopkins Press.

- Ervin, S. M. (1961). Changes with age in the verbal determinants of word association. American Journal of Psychology, 74, 361-372.
- Francis, H. (1972). Towards an explanation of the syntagmatic-paradigmatic shift. Child Development, 43, 949-958.
- Francis, W. N., & Kucera, H. (1982). Frequency analysis of English usage: Lexicon and grammar. Boston, MA: Houghton Mifflin Company.
- Friedman, R. B. & Albert, M. L. (1985). Alexia. In K. M. Heilman & E. Valenstein (Eds.), Clinical neuropsychology (2nd ed.). New York: Oxford University Press.
- Friedman, D., Putnam, L., Ritter, W., Hamberger, M., & Berman, S. (1992). A developmental event-related potential study of picture matching in children, adolescents and young adults: A replication and extension. Psychophysiology, 29, 593-610.
- Geschwind, N. (1970). The organization of language and the brain. Science, 170, 940-944.
- Gewirth, L. R., Shindler, A., G., & Hier, D. B. (1984). Altered patterns of word associations in dementia and aphasia. Brain and Language, 21, 307-317.
- Goodglass, H. (1973). Studies on the grammar of aphasics. In H. Goodglass & S. E. Blumstein (Eds.), Psycholinguistics and aphasia. Baltimore, MD: Johns Hopkins University Press.
- Goodglass, H., & Geschwind, N. (1976). Language disorders (aphasia). In E. C. Carterette & M. P. Friedman (Eds.), Handbook of perception, vol. 7. New York: Academic Press.
- Grober, E., Perecman, E., Kellar, L., & Brown, J. (1980). Lexical knowledge in anterior and posterior aphasics. Brain and Language, 10, 318-330.
- Gross, D., Fischer, U. & Miller, G. A. (1989). The organization of adjectival meanings. Journal of Memory and Language, 28, 92-106.
- Grossberg, S. & Stone, G. (1986). Neural dynamics of word recognition and recall: Attentional priming, learning, and resonance. Psychological Review, 93, 46-74.
- Grossman, M. & Carey, S. (1987). Selective word-learning deficits in aphasia. Brain and Language, 32, 306-324.

- Heidenheimer, P. (1978). A comparison of the roles of exemplar, action, coordinate, and superordinate relations in semantic processing of 4- and 5-year old children. Journal of Experimental Child Psychology, 25, 143-159.
- Heilman, K. M. & Scholes, R. J. (1976). The nature of comprehension errors in Broca's, conduction and Wernicke's aphasia. Cortex, 12, 258-265.
- Hines, D., Czerwinski, M., Sawyer, P. K., & Dwyer, M. (1986). Automatic semantic priming: Effect of category exemplar level and word association level. Journal of Experimental Psychology: Human Perception and Performance, 12, 370-379.
- Hodgson, J. M. (1991). Informational constraints on pre-lexical priming. Language and Cognitive Processes, 6, 169-205.
- Holcomb, P. J. (1988). Automatic and attentional processing: An event-related brain potential analysis of semantic priming. Brain and Language, 35, 66-85.
- Holcomb, P. J. (1993). Semantic priming and stimulus degradation: Implications for the role of the N400 in language processing. Psychophysiology, 30, 47-61.
- Holcomb, P. J. & Neville, H. J. (1990). Auditory and visual semantic priming in lexical decision: A comparison using event-related brain potentials. Language and Cognitive Processes, 5, 281-312.
- Holcomb, P. J. & Neville, H. J. (1991). Natural speech processing: An analysis using event-related brain potentials. Psychobiology, 19, 286-300.
- Howard, D. V. (1979). Restricted word association norms for adults between the ages of 20 and 80. Technical Report NIA-79-2.
- Howard, D. V., McAndrews, M. P., & Lasaga, M. I. (1981). Semantic priming of lexical decisions in young and old adults. Journal of Gerontology, 36, 707-714.
- Howard, D. V., Shaw, R. J., & Heisey, J. G. (1986). Aging and the time course of semantic activation. Journal of Gerontology, 41, 195-203.
- Huttenlocher, J. & Lui, F. (1979). The semantic organization of some simple nouns and verbs. Journal of Verbal Learning and Verbal Behavior, 18, 141-162.

- Jakobson, R. (1971). Two aspects of language and two types of aphasic disturbance. In R. Jakobson, Studies on child language and aphasia and in R. Jakobson and M. Halle, Fundamentals of language (1956). The Hague: Mouton.
- Katz, W. F. (1988). An investigation of lexical ambiguity in Broca's aphasics using an auditory lexical priming technique. Neuropsychologia, 26, 747-752.
- Kleiman, G. M. (1980). Sentence frame contexts and lexical decisions: Sentence-acceptability and word-relatedness effects. Memory and Cognition, 8, 336-344.
- Kolk, H. H. J., & Friederici, A. D. (1985). Strategy and impairment in sentence understanding by Broca's and Wernicke's aphasics. Cortex, 21, 47-67.
- Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. Science, 207, 203-205.
- Kutas, M. & Hillyard, S. A. (1982). The lateral distribution of event-related potentials during sentence processing. Neuropsychologia, 20, 579-590.
- Kutas, M., & Hillyard, S. A. (1983). Event-related potentials to grammatical errors and semantic anomalies. Memory and Cognition, 11, 539-550.
- Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. Nature, 307, 161-163.
- Kutas, M., & Hillyard, S. A. (1989). An electrophysiological probe of incidental semantic association. Journal of Cognitive Neuroscience, 1, 38-49.
- Kutas, M., Neville, H. J., & Holcomb, P. J. (1987). A preliminary comparison of the N400 response to semantic anomalies during reading, listening and signing. In R.J. Ellington, N.M.F. Murray, & A.M. Halliday (Eds.), The London Symposia (EEG Suppl. 39). Holland: Elsevier Science Publishers.
- Kutas, M. & Van Petten, C. (1988) Event related potential studies of language. In P. K. Ackles, J. R. Jennings & M. G. H. Coles (Eds.), Advances in psychophysiology. Greenwich, Ct.: JAI Press.
- Lakoff, G. (1987). Women, fire and dangerous things. Chicago, Il: University of Chicago Press.

- Linebarger, M. C., Schwartz, M. F., & Saffran, E. M. (1983). Sensitivity to grammatical structure in so-called agrammatic aphasics. Cognition, 13, 361-392.
- Lippman, M. Z. (1971). Correlates of contrast word associations: Developmental trends. Journal of Verbal Learning and Verbal Behavior, 10, 392-399.
- Lovelace, E. A. & Colley, S. (1982). Free Associations of older adults to single words and conceptually related word triads. Journal of Gerontology, 37, 432-437.
- Lucariello, J., Kyratzis, A. & Nelson, K. (1992). Taxonomic knowledge: What kind and when? Child Development, 63, 978-998.
- Lucariello, J. & Nelson, K. (1985). Slot-filler categories as memory organizers for young children. Developmental Psychology, 21, 272-282.
- Lukatela, G., Carello, C., Kostic, A., & Turvey, M. T. (1988). Low-constraint facilitation in lexical decision with single-word contexts. American Journal of Psychology, 101, 15-29.
- Lukatela, G., Kostic, A., Todorovic, D., Carello, C. & Turvey, M. T. (1987). Type and number of violations and the grammatical congruency effect in lexical decision. Psychological Research, 49, 37-43.
- Lupker, S. J. (1984). Semantic priming without association: A second look. Journal of Verbal Learning and Verbal Behavior, 23, 709-733.
- Luria, A. R. (1973). Two basic kinds of aphasic disorders. Linguistics, 115, 57-66.
- Luria, A. R. (1976). Cognitive development: Its cultural and social foundations. Cambridge, MA: Harvard University Press.
- Mandler, J. M. (1979). Categorical and schematic organization in memory. In C.R. Puff (Ed.), Memory organization and structure. New York: Academic Press.
- Mandler, J. M., Fivush, R., & Reznick, J. S. (1987). The development of contextual categories. Cognitive Development, 2, 339-354.

- McCallum, W. C., Farmer, S. F. and Pocock, P. V. (1984). The effects of physical and semantic incongruities on auditory event-related potentials. Electroencephalography and Clinical Neurophysiology, 59, 477-488.
- McCauley, C., Weil, C. M., & Sperber, R. D. (1976). The development of memory structure as reflected by semantic-primary effects. Journal of Experimental Child Psychology, 22, 511-518.
- McCleary, C. & Hirst, W. (1986). Semantic classification in aphasia: A study of basic, superordinate, and function relations. Brain and Language, 27, 199-209.
- McClelland, J. L. (1979). On the time relations of mental processes: An examination of systems of processes in Cascade. Psychological Review, 86, 287-330.
- McCloskey, M. & Glucksberg, S. (1979). Decision processes in verifying category membership statements: Implications for models of semantic memory, Cognitive Psychology, 11, 1-37.
- McCusker, L. X., Hillinger, M. L., Bias, R. G. (1981). Phonological recoding and reading. Psychological Bulletin, 89, 217-245.
- McNeill, D. (1966). A study of word association. Journal of Verbal Learning and Verbal Behavior, 5, 548-557.
- Miceli, G., Silveri, M. C., Villa, G. & Caramazza, A. (1984). On the basis for the agrammatic's difficulty in producing main verbs. Cortex, 20, 207-220.
- Milberg, W., & Blumstein, S. E. (1981). Lexical decision and aphasia: Evidence for semantic processing. Brain and Language, 14, 371-385.
- Miller, G.A. & Fellbaum, C. (1991). Semantic networks of English. Cognition, 41, 197-229.
- Miller, G. A. & Johnson-Laird, P. N. (1976). Language and Perception. Cambridge, MA: Harvard University Press.
- Moran, L. J. (1981). Evidence for the universal structure of the child's cognitive dictionary. Journal of General Psychology, 105, 149-154.
- Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. Journal of Experimental Psychology: General, 106, 226-254.

- Nelson, K. (1977). The syntagmatic-paradigmatic shift revisited: A review of research and theory. Psychological Bulletin, 84, 93-116.
- Nelson, K. (1985). Making sense: The acquisition of shared meaning. New York: Academic Press.
- Nelson, K. (1986). Event knowledge: Structure and function in development. Hillsdale, New Jersey: Lawrence Erlbaum.
- Nelson, K. (1991). Event knowledge and the development of language functions. In J.F. Miller (Ed.), Research on child language disorders: A decade of progress. Austin, Texas: Pro-ed.
- Nelson, K & Hudson, J. (1984). Scripts and memory: Functional relationships in development. In F.E. Weinert & M. Perlmutter (Eds.), Memory development: Universal changes and individual differences.
- Nigam, A., Hoffman, J. E., & Simons, R. F. (1992). N400 to semantically anomalous pictures and words. Journal of Cognitive Neuroscience, 4, 15-22.
- Ornstein, P. A. & Corsale, K. (1979). Organizational factors in children's memory. In C.R. Puff (Ed.), Memory organization and structure. New York: Academic Press.
- Palermo, D. S. (1971). Characteristics of word association responses obtained from children in grades one through four. Developmental Psychology, 5, 118-123.
- Palermo, D. S. & Jenkins, J. J. (1964). Word association norms: Grade school through college. Minneapolis, MN.: University of Minnesota Press.
- Pellegrino, J. W. & Ingram, A. L. (1979). Processes, products, and measures of memory organization. In C.R. Puff (Ed.), Memory organization and structure. New York: Academic Press.
- Petrey, S. (1977). Word associations and the development of lexical memory. Cognition, 5, 57-71.
- Posner, M. I. (1978). Chronometric explorations of mind. Hillsdale, N. J.: Lawrence Erlbaum.
- Posner, M. I. & Snyder, C. R. R. (1975). Facilitation and inhibition in the processing of signals. In Rabbitt, P.M.A. & Dornic, S. (Eds.), Attention and performance V. New York: Academic Press.

- Postman, L. & Keppel, G. (Eds.) (1970). Norms of word association. New York, NY: Academic Press.
- Radeau, M. (1983). Semantic priming between spoken words in adults and children. Canadian Journal of Psychology, 37, 557-564.
- Ratcliff, R. (1978). A theory of memory retrieval. Psychological Review, 85, 59-108.
- Richards, D. D. & Goldfarb, J. (1986). The episodic memory model of conceptual development: An integrative viewpoint. Cognitive Development, 1, 183-219.
- Ritter, W., Ford, J. M., Gaillard, A. W. K., Harter, M. R., Kutas, M., Naatanen, R., Polich, J., Renault, B., & Rohrbaugh, J. (1984). Cognitive and event-related potentials: The relation of negative potentials and cognitive processes. Annals of the New York Academy of Sciences, 425, 24-38.
- Ritter, W., Simson, R. & Vaughan, H. G., Jr. (1988). Effects of the amount of stimulus information processing on negative event-related potentials. Electroencephalography and Clinical Neurophysiology, 69, 244-258.
- Routh, D. K. & Tweney, R. D. (1972). Effects of paradigmatic response training on children's word associations. Journal of Experimental Child Psychology, 14, 398-407.
- Rugg, M. D. (1985). The effects of semantic priming and word repetition on event-related potentials. Psychophysiology, 22, 642-647.
- Saffran, E. M., Schwartz, M. F., & Marin, O. S. M. (1980). The word order problem in agrammatism: Production. Brain and Language, 10, 263-280.
- Schwartz, M. F., Saffran, E. M., & Marin, O. S. M. (1980). The word order problem in agrammatism: Comprehension. Brain and Language, 10, 249-262.
- Seidenberg, M. S. and McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. Psychological Review, 96, 523-568
- Sell, M. A. (1992). The development of children's knowledge structures: Events, slots, and taxonomies. Journal of Child Language, 19, 659-676.

- Shank, R. C. & Abelson, R. P. (1977a). Scripts, plans, and knowledge. In P.N. Johnson-Laird & P.C. Wason (Eds.), Thinking: Readings in cognitive science. NY: Cambridge University Press.
- Shank, R. C. & Abelson, R. P. (1977b). Scripts, plans, goals and understanding: An inquiry into human knowledge structures. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Sharp, D. & Cole, M. (1972). Patterns of responding in the word associations of West African children. Child Development, 43, 55-65.
- Shoben, E. J. (1982). Semantic and lexical decision. In C.R. Puff (Ed.), Handbook of Research Methods in Human Memory and Cognition. New York: Academic Press.
- Smiley, S. S. & Brown, A. L. (1979). Conceptual preference for thematic or taxonomic relations: A nonmonotonic age trend from preschool to old age. Journal of Experimental Child Psychology, 28, 249-257.
- Smith, E. E. (1978). Theories of semantic memory. In W.K. Estes (Ed.), Handbook of learning and cognitive processes, vol. 6: Linguistic functions in cognitive theories. Hillsdale, NJ: Erlbaum.
- Smith, E. E.; Shoben, E. J. & Rips, L. J. (1974). Structure and process in semantic memory: A featural model for semantic decision. Psychological Review, 81, 214-241.
- Stuss, D. I., Sarazin, F. F., Leech, E. E., & Picton, T. W. (1983). Event-related potentials during naming and mental rotation. Electroencephalography and Clinical Neurophysiology, 56, 133-146.
- Tartter, V. C. (1986). Language Processes. New York: Holt, Rinehart and Winston.
- Tulving, E. (1972). Episodic and semantic memory. In E. Tulving and W. Donaldson (Eds.), Organization of memory. NY: Academic Press.
- Van Petten, C. & Kutas, M. (1991). Electrophysiological evidence for the flexibility of lexical processing. In G. B. Simpson (Ed.), Understanding word and sentence. Holland: Elsevier Science Publishers.
- Vygotsky, L. (1986). Thought and Language. Cambridge, Mass: MIT Press. (Original work published in 1934)

- Weingarten, M & Anisfeld, M. (1981). The syntagmatic-paradigmatic shift in dichotic listening. Journal of Experimental Child Psychology, 31, 271-278.
- Wilding, J. M. (1988). The interaction of word frequency and stimulus quality in the lexical decision task: Now you see it, now you don't. Quarterly Journal of Experimental Psychology, 40A, 757-770.
- Williams, S.E. & Canter, G. J. (1987). Action-naming performance in four syndromes of aphasia. Brain and Language, 32, 124-136.
- Woodrow, H. & Lowell, F. (1916). Children's association frequency tables. Psychological Monographs, 97.
- Zurif, E. B. (1980). Language mechanisms: A neuropsychological perspective. American Scientist, 68, 305-311.
- Zurif, E. B., Caramazza, A., Myerson, R., & Galvin, J. (1974). Semantic feature representations for normal and aphasic language. Brain and Language, 1, 167-187.