# IS REPETITION PRIMING AUTOMATIC? STUDIES OF THE ROLE OF ATTENTION IN IMPLICIT AND EXPLICIT MEMORY TASKS

by

Maxwell Twum

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
at
Dalhousie University
Halifax, Nova Scotia
August, 1996

ISBN 0-612-15939-6

Name TWUM, MAXWELL

*Dissertation Abstracts International* is arranged by broad, general subject categories. Please select the one subject which most nearly describes the content of your dissertation. Enter the corresponding four-digit code in the spaces provided.

PSYCHOLOGY | 0623 | U·M·I

SUBJECT TERM | SUBJECT CODE

## Subject Categories

# THE HUMANITIES AND SOCIAL SCIENCES

### COMMUNICATIONS AND THE ARTS
Architecture .... 0729
Art History .... 0377
Cinema .... 0900
Dance .... 0378
Fine Arts .... 0357
Information Science .... 0723
Journalism .... 0391
Library Science .... 0399
Mass Communications .... 0708
Music .... 0413
Speech Communication .... 0459
Theater .... 0465

### EDUCATION
General .... 0515
Administration .... 0514
Adult and Continuing .... 0516
Agricultural .... 0517
Art .... 0273
Bilingual and Multicultural .... 0282
Business .... 0688
Community College .... 0275
Curriculum and Instruction .... 0727
Early Childhood .... 0518
Elementary .... 0524
Finance .... 0277
Guidance and Counseling .... 0519
Health .... 0680
Higher .... 0745
History of .... 0520
Home Economics .... 0278
Industrial .... 0521
Language and Literature .... 0279
Mathematics .... 0280
Music .... 0522
Philosophy of .... 0998
Physical .... 0523
Psychology .... 0525
Reading .... 0535
Religious .... 0527
Sciences .... 0714
Secondary .... 0533
Social Sciences .... 0534
Sociology of .... 0340
Special .... 0529
Teacher Training .... 0530
Technology .... 0710
Tests and Measurements .... 0288
Vocational .... 0747

### LANGUAGE, LITERATURE AND LINGUISTICS
Language
- General .... 0679
- Ancient .... 0289
- Linguistics .... 0290
- Modern .... 0291

Literature
- General .... 0401
- Classical .... 0294
- Comparative .... 0295
- Medieval .... 0297
- Modern .... 0298
- African .... 0316
- American .... 0591
- Asian .... 0305
- Canadian (English) .... 0352
- Canadian (French) .... 0355
- English .... 0593
- Germanic .... 0311
- Latin American .... 0312
- Middle Eastern .... 0315
- Romance .... 0313
- Slavic and East European .... 0314

### PHILOSOPHY, RELIGION AND THEOLOGY
Philosophy .... 0422
Religion
- General .... 0318
- Biblical Studies .... 0321
- Clergy .... 0319
- History of .... 0320
- Philosophy of .... 0322

Theology .... 0469

### SOCIAL SCIENCES
American Studies .... 0323
Anthropology
- Archaeology .... 0324
- Cultural .... 0326
- Physical .... 0327

Business Administration
- General .... 0310
- Accounting .... 0272
- Banking .... 0770
- Management .... 0454
- Marketing .... 0338

Canadian Studies .... 0385
Economics
- General .... 0501
- Agricultural .... 0503
- Commerce-Business .... 0505
- Finance .... 0508
- History .... 0509
- Labor .... 0510
- Theory .... 0511

Folklore .... 0358
Geography .... 0366
Gerontology .... 0351
History
- General .... 0578
- Ancient .... 0579
- Medieval .... 0581
- Modern .... 0582
- Black .... 0328
- African .... 0331
- Asia, Australia and Oceania 0332
- Canadian .... 0334
- European .... 0335
- Latin American .... 0336
- Middle Eastern .... 0333
- United States .... 0337

History of Science .... 0585
Law .... 0398
Political Science
- General .... 0615
- International Law and Relations .... 0616
- Public Administration .... 0617

Recreation .... 0814
Social Work .... 0452
Sociology
- General .... 0626
- Criminology and Penology .... 0627
- Demography .... 0938
- Ethnic and Racial Studies .... 0631
- Individual and Family Studies .... 0628
- Industrial and Labor Relations .... 0629
- Public and Social Welfare .... 0630
- Social Structure and Development .... 0700
- Theory and Methods .... 0344

Transportation .... 0709
Urban and Regional Planning .... 0999
Women's Studies .... 0453

# THE SCIENCES AND ENGINEERING

### BIOLOGICAL SCIENCES
Agriculture
- General .... 0473
- Agronomy .... 0285
- Animal Culture and Nutrition .... 0475
- Animal Pathology .... 0476
- Food Science and Technology .... 0359
- Forestry and Wildlife .... 0478
- Plant Culture .... 0479
- Plant Pathology .... 0480
- Plant Physiology .... 0817
- Range Management .... 0777
- Wood Technology .... 0746

Biology
- General .... 0306
- Anatomy .... 0287
- Biostatistics .... 0308
- Botany .... 0309
- Cell .... 0379
- Ecology .... 0329
- Entomology .... 0353
- Genetics .... 0369
- Limnology .... 0793
- Microbiology .... 0410
- Molecular .... 0307
- Neuroscience .... 0317
- Oceanography .... 0416
- Physiology .... 0433
- Radiation .... 0821
- Veterinary Science .... 0778
- Zoology .... 0472

Biophysics
- General .... 0786
- Medical .... 0760

### EARTH SCIENCES
Biogeochemistry .... 0425
Geochemistry .... 0996
Geodesy .... 0370
Geology .... 0372
Geophysics .... 0373
Hydrology .... 0388
Mineralogy .... 0411
Paleobotany .... 0345
Paleoecology .... 0426
Paleontology .... 0418
Paleozoology .... 0985
Palynology .... 0427
Physical Geography .... 0368
Physical Oceanography .... 0415

### HEALTH AND ENVIRONMENTAL SCIENCES
Environmental Sciences .... 0768
Health Sciences
- General .... 0566
- Audiology .... 0300
- Chemotherapy .... 0992
- Dentistry .... 0567
- Education .... 0350
- Hospital Management .... 0769
- Human Development .... 0758
- Immunology .... 0982
- Medicine and Surgery .... 0564
- Mental Health .... 0347
- Nursing .... 0569
- Nutrition .... 0570
- Obstetrics and Gynecology .... 0380
- Occupational Health and Therapy .... 0354
- Ophthalmology .... 0381
- Pathology .... 0571
- Pharmacology .... 0419
- Pharmacy .... 0572
- Physical Therapy .... 0382
- Public Health .... 0573
- Radiology .... 0574
- Recreation .... 0575
- Speech Pathology .... 0460
- Toxicology .... 0383

Home Economics .... 0386

### PHYSICAL SCIENCES
#### Pure Sciences
Chemistry
- General .... 0485
- Agricultural .... 0749
- Analytical .... 0486
- Biochemistry .... 0487
- Inorganic .... 0488
- Nuclear .... 0738
- Organic .... 0490
- Pharmaceutical .... 0491
- Physical .... 0494
- Polymer .... 0495
- Radiation .... 0754

Mathematics .... 0405
Physics
- General .... 0605
- Acoustics .... 0986
- Astronomy and Astrophysics .... 0606
- Atmospheric Science .... 0608
- Atomic .... 0748
- Electronics and Electricity .... 0607
- Elementary Particles and High Energy .... 0798
- Fluid and Plasma .... 0759
- Molecular .... 0609
- Nuclear .... 0610
- Optics .... 0752
- Radiation .... 0756
- Solid State .... 0611

Statistics .... 0463

#### Applied Sciences
Applied Mechanics .... 0346
Computer Science .... 0984

Engineering
- General .... 0537
- Aerospace .... 0538
- Agricultural .... 0539
- Automotive .... 0540
- Biomedical .... 0541
- Chemical .... 0542
- Civil .... 0543
- Electronics and Electrical .... 0544
- Heat and Thermodynamics .... 0348
- Hydraulic .... 0545
- Industrial .... 0546
- Marine .... 0547
- Materials Science .... 0794
- Mechanical .... 0548
- Metallurgy .... 0743
- Mining .... 0551
- Nuclear .... 0552
- Packaging .... 0549
- Petroleum .... 0765
- Sanitary and Municipal .... 0554
- System Science .... 0790

Geotechnology .... 0428
Operations Research .... 0796
Plastics Technology .... 0795
Textile Technology .... 0994

### PSYCHOLOGY
General .... 0621
Behavioral .... 0384
Clinical .... 0622
Developmental .... 0620
Experimental .... 0623
Industrial .... 0624
Personality .... 0625
Physiological .... 0989
Psychobiology .... 0349
Psychometrics .... 0632
Social .... 0451

To the womb that nurtured me,
the breasts that suckled me,
and the hands and wisdom
that years before I reached this point in my life,
carefully charted the course on which I was to travel.
This thesis is dedicated to Afrakoma--my Mother.

Table of Contents

Pagination Error

Text Complete

Erreur de pagination

Le texte est complet

Abstract

Many studies have shown that the manipulation of attention during encoding of information impairs explicit memory but spares implicit memory. This insensitivity of implicit memory to attention manipulation has been attributed to automatic processes during encoding of information and repetition priming. The presumed automatic mechanisms underlying these findings were examined with a modified Stroop color-word task in a filtering paradigm. Different groups of subjects either read the target words (Read Word condition), named the ink colors of the target words (Name Word Color condition) or named the ink colors of distractor stimuli presented simultaneously above or below a word (Name XX Color condition). Although attention to the presented words was expected to be reduced in the color naming tasks, automatic processing of words was expected in the Name Word Color condition. Whether this automatic processing of words would affect repetition priming was examined by testing with a word fragment completion test in Experiment 1, word stem completion tests in Experiments 2 and 3, and a lexical decision task in Experiment 4. Explicit testing with cued recall using word fragment completion, word stem completion, or recognition was also included. Word reading in Experiments 1-3 consistently produced significantly higher repetition priming and cued recall compared to color naming the words or XXs. In contrast, the lexical decision task in Experiment 4 produced significant repetition priming in all conditions whereas explicit recognition of the target words was highest in the Read Word condition. The results suggest that repetition priming can be affected by manipulating visual directed attention. The effects of this manipulation, however, may vary depending on the particular implicit task used to assess priming. It was concluded, in the light of these results, that automatic processing of to-be-ignored information does not necessarily lead to dissociation between implicit and explicit memory. The view that the manipulation of attention does not affect implicit memory while affecting explicit memory is, thus, in need of revision.

## Acknowledgments

I wish to express my sincere gratitude to my thesis supervisor for the past three years, Dr. Gail A. Eskes, for offering me the opportunity to pursue my doctoral degree under her supervision. She gave me the room I needed to develop my research interests through these past years, and working with her has been a very fruitful and rewarding experience for me, indeed. I also wish to express my gratitude to Dr. Raymond Klein who offered me good guidance when I needed it. Also, the suggestions of Dr. Chris Moore have been valuable for the completion of this thesis. The list will not be complete, however, without acknowledging the immense technical and programming assistance I received from John Christie. It was his genius that made the running of these experiments possible and I am sincerely grateful for his help.

Is Repetition Priming Automatic? Studies of the Role of Attention in Implicit and Explicit Memory Tasks

Memory is not a unitary phenomenon, but can be broken down into different processes or systems that are accessed by different tests. One division is between implicit and explicit memory (Schacter & Graf, 1985). Implicit memory refers to memory for information acquired during a specific study episode, that is expressed in tests in which the subject is not required to retrieve the information deliberately or consciously. Implicit memory tests may be divided into two main categories: item specific and procedural (see Moscovitch, Goshen-Gottstein, & Vriezen, 1994, for a detailed review). Item specific implicit memory tests are those that require memory for specific items such as words, pictures, or objects, whereas procedural implicit memory tests assess the acquisition and retention of cognitive or sensorimotor skills required for solving puzzles or reading transformed scripts. Procedural implicit memory tests are only mentioned in passing; they are not relevant for current purposes.

Implicit memory in item specific tests is inferred from changes in the efficiency or accuracy of processing a previously encountered item when it is repeated, or in the probability and efficiency that it is reproduced or elicited by appropriate cues. This change in processing efficiency is termed priming (cf. Tulving & Schacter, 1990) because the initial presentation of the item is assumed to "prime" it and make it more readily accessible for later processing (Moscovitch et al., 1994). Priming or repetition priming is typically calculated by subtracting a performance measure such as latency or completion rate for unencountered control items from that of previously encountered items.

Item specific implicit tests may be further subdivided into perceptual or conceptual types (cf. Jacoby, 1983). This subdivision is based on the type of test cues that are supplied for the generation of responses. Perceptual tests may reinstate the material studied in whole or in part. In these tests, the subject can be required to supply or identify an item on the basis of perceptual information. Alternatively, the item may be degraded in terms of elimination of features such as letters or other parts, as in word fragment completion, word stem completion, or picture fragment completion tests. The item may also be presented very briefly to the subject as in word identification tests. For example, if "COMPUTER" is in a list of studied words, the first two or three letters (COM_____) may be presented as a cue in a word stem completion test. The cue in a word fragment completion test will be a fragmented word (e.g., _O _ P U _E _). In picture completion, parts of a studied picture may be presented as cues. Because subjects complete these cues with the first word or name that comes to mind, the completion of the cue with a previously studied word or picture gives an indication of implicit memory. In other tests, like the lexical decision task, a word is presented in full without degradation and the decision latency is compared between old and new words.

For conceptual implicit memory tests (see Jacoby, 1983; Blaxton, 1989), the target items are generated in response to semantic or conceptual cues. Examples of these tests include the category instance generation test, and answering general knowledge questions. In the category instance generation test, for example, a subject may study a list of words that may include "carrot," "spinach," and, "cabbage." Following the study task, the subject is asked to generate examples of the category "vegetables." The production of examples from the studied list (i.e., carrot, cabbage), rather than from a control list of unstudied examples in the same category, gives an indication of priming of the studied words. In the general knowledge questions test (cf. Blaxton, 1989), a subject may study a list of words and subsequently answer general knowledge questions. The answers to some of the questions would be the specific items the subject studied. The greater provision of answers from the list of studied items compared to unstudied control items provides the index of priming.

Explicit memory, on the other hand, involves the deliberate use of previously studied information in the completion of a memory test. Explicit memory tests include free recall, cued recall, and recognition (Graf & Schacter, 1985; Schacter & Graf, 1986; Schacter, 1987, 1990).

## Operational Definition of Implicit and Explicit Memory

The classification of memory as implicit and explicit is by no means the only classification available. Observations of different aspects of memory have led theorists to postulate different classes of memory tasks, processes, or systems. Thus, memory has been classified as implicit-explicit (Graf & Schacter, 1985) procedural-declarative (Squire, 1986, 1987) data driven-conceptually driven processing (Jacoby, 1983; Roediger & Blaxton, 1987), memory-habit (Mishkin, Malamut, & Bachevalier, 1984), "knowing how"-"knowing that" (Cohen & Squire, 1980), and episodic-semantic (Tulving, 1985). A discussion of these different attempts to explain different aspects of memory is beyond the scope of this dissertation. The discussion will focus, instead, on the implicit-explicit distinction, to be used as the framework in this thesis.

Richardson-Klavehn and Bjork (1988) have observed that the terms "implicit" and "explicit" memory have been used interchangeably to refer to tasks and method of measurement or to hypothetical forms of memory. When implicit memory is defined as being revealed on tasks that do not require reference to a specific prior episode (Schacter, 1985), this suggests memory that is task-based. A different meaning is conveyed, however, when implicit memory is defined as being revealed when performance on a task is facilitated in the absence of conscious recollection (Graf & Schacter, 1985). The second definition implies that implicit memory is inferred from a dissociation between two measures of memory. Richardson-Klavehn and Bjork have made similar observations about the confusion surrounding explicit memory. Explicit memory has been defined as requiring conscious recollection of previous experiences (Graf & Schacter, 1985) or as requiring conscious awareness of the learning episode for successful performance (Roediger & Blaxton, 1987). "Conscious recollection" or "awareness" conveys two meanings: that (a) the awareness is based on task instructions referring to a prior episode (task-based) or (b) that the subject has a subjective awareness of reexperiencing the episode (mental state). These dual interpretations confuse the meaning of the terms.

Similar sentiments have been expressed by Dunn and Kirsner (1989) who have observed that many theorists fail to separate task from process descriptions. Dunn and Kirsner have argued that using the distinction between implicit and explicit memory simultaneously to describe different memory tasks and the processes that underlie these tasks creates a problem. It assumes that a task of a particular type is solved with a specific process or processing system in such a way that the task performance is a direct reflection of the operation of its underlying mechanism. According to Dunn and Kirsner, the assumption that tasks function as a transparent window that can reveal underlying mental processes or processing systems cannot be justified because the task may draw upon many different processing resources.

Because of these definitional problems, some researchers (Dunn & Kirsner, 1989; Johnson & Hasher, 1987; Light & LaVoie, 1993; Merikle & Reingold, 1991, 1992; Richardson-Klavehn & Bjork, 1988) have advocated *"direct"* and *"indirect"* tests as corresponding, yet better alternative terms to explicit and implicit memory, respectively. They reason that this terminology makes no assumptions about the forms of memory tapped by the tests. Besides, one can never be entirely certain whether a task is performed on the basis of implicit memory alone. A subject may become aware of the study episode when performing a task supposed to be implicit.

Schacter (1990) has argued, however, that the indirect/direct distinction suffers the same potential problems inherent in the implicit-explicit distinction. A nominally "indirect" test like a word stem completion test may, nevertheless, be solved by subjects using intentional retrieval strategies once they "catch on" to the nature of the task. This situation immediately renders a supposedly "indirect" task a "direct" task. Schacter has argued that it is unnecessary to abandon the implicit/explicit distinction despite the definitional problems, especially when the supposedly better characterization is subject to the same problems it purports to rectify.

Roediger (1990a) has also argued on behalf of the implicit/explicit distinction because it clearly reflects differences in retrieval operations (see Roediger & Blaxton, 1987). He argues further, that the implicit/explicit distinction implies that access to memory operates differently in the two cases. The indirect/direct dichotomy, by contrast, seems to imply that the same knowledge or form of memory is being accessed. If this is so, strong crossover dissociation would not be expected between the direct and indirect tests. These dissociations have, however, been shown repeatedly (e.g., Blaxton, 1989; Jacoby, 1983; Srinivas & Roediger, 1990), thus suggesting that the direct and indirect dichotomy is not a useful distinction.

Dunn and Kirsner have called for theories that specify the kinds of processes that operate in memory and how these processes are affected by experimental variables. The transfer appropriate processing approach (Roediger, 1990b) is an example of such a theory. The key assumption of this theory is that memory performance will benefit to the extent that operations required at test recapitulate or overlap the encoding operations performed during the learning episode. A secondary assumption is that implicit and explicit tests typically require different retrieval operations. The transfer appropriate processing approach also assumes that most explicit tests rely on the encoded meaning of concepts or semantic processing, elaborate encoding, mental imagery, etc., whereas many implicit tests rely heavily on a match between perceptual operations between study and test. There is some evidence to suggest that the degree of overlap between processing operations at study and test is a more viable interpretation of dissociation in memory tests than is the idea of separate memory systems underlying different tasks (see Blaxton, 1989). Blaxton showed, for example, that answering general knowledge questions (a conceptual implicit memory test) was most enhanced after subjects had generated a target word in response to a cue compared to reading the target word itself at study. In contrast, there was significantly better completion of word fragments (a perceptual implicit memory test) after subjects had read the target words compared to generating them from cues. The processing (transfer appropriate processing) approach that generally emphasizes the overlap between processes engaged at study and test is a parsimonious hypothesis for interpreting the data on dissociations between implicit and explicit memory in normal subjects (Blaxton, 1989; Roediger & Blaxton, 1987; Roediger, Weldon, & Challis, 1989; Srinivas & Roediger, 1990).

The difficulty expressed in this ongoing debate on definitional issues centers on the exact nature of implicit memory and how we can be assured that the putative implicit performance is not influenced by explicit processes and vice versa. Indeed, the debate about the precise terminology to characterize dissociations in memory relates to the desire by researchers to ensure that performance on implicit tests like word stem completion, word fragment completion, and lexical decision tasks is not due to explicit retrieval processes. One implication of this discussion is that the distinction between implicit and explicit memory is not so easily made. The difficulty lies in determining the influence of intentional retrieval in the performance of a task.

In the light of the foregoing, and to avoid the likelihood of dual interpretation of definitions, "implicit memory" in this dissertation will refer to performance on a test that, following the instructions provided, is done without deliberate *or intentional* retrieval of information from a previous study episode. This definition does not make any assumptions about underlying processes or processing systems. The difference between performance on the studied items and nonstudied items will be taken as the magnitude of the priming effect. Explicit memory will refer to performance on a test that, following the instructions provided, is motivated and guided by the intentional retrieval of information from a previous study episode.

## Implicit-Explicit Memory Dissociation

The differential performance on implicit and explicit memory tests resulting either from brain damage or experimental manipulation is referred to as dissociation. For example, as a result of brain damage some amnesic patients are unable to explicitly remember previously learned information. Their performance on explicit tests is thus significantly lower than that of a control group of normal, neurologically intact subjects. The amnesic subjects, however, may perform equally well compared to normal controls when memory for the information is assessed implicitly. Numerous studies have demonstrated this kind of dissociation (see for example, Graf & Schacter, 1985; Graf, Shimamura, & Squire, 1985; Graf, Squire, & Mandler, 1984). Experimental manipulations can also produce this dissociation in normal subjects. Whereas some manipulations produce significant differences when memory for studied information is tested with explicit free recall, cued recall, or recognition, these manipulations do not affect the performance of subjects when memory for studied information is tested on implicit tests like word fragment completion, word stem completion, word identification, or lexical decision task.

Some of the experimental manipulations used in the study of implicit-explicit memory dissociations in normal subjects include levels of processing (e.g., Graf & Mandler, 1984; Jacoby & Dallas, 1981) and changes in the modality and surface features in which information is learned and tested (Jacoby & Dallas, 1981; Kirsner, Milech, & Standen, 1983).

In levels of processing manipulations, elaborate semantic processing of information during study produces significant differences in memory performance. Subjects who study the information for its semantic interpretation show better explicit memory on a later test compared to those who learn the information superficially. There is, however, relatively little difference in how the semantic and superficial groups perform on implicit memory tests. According to Graf (1994), these findings "suggest that priming is an automatic consequence of studying familiar words, whereas explicit memory test performance varies with the specific requirements of each study task (p. 683)."

A recent review has suggested, however, that implicit memory tests can be affected by the levels to which information is studied. Challis and Brodbeck (1992) showed a significant levels of processing effect in word fragment completion tests when semantic and physical processing of words were manipulated either between groups or in blocks within group. The levels of processing effect was nonsignificant, however, when semantic and physical processing were changed at random from item to item within group. By contrast, no levels of processing effects were found in another study (Roediger, Weldon, Stadler, & Riegler, 1992) that assessed implicit memory with word fragment and word stem cues. Roedig and his associates showed, however, that the same cues produced a significant levels of processing effect in an explicit memory test. It is not clear why these different results were obtained. Moscovitch et al. (1994) have observed that the levels of processing effect is not observed in amnesic patients and is eliminated in normal subjects who are truly unaware of the relation between study and test items. They suggest, therefore, that implicit memory tests may indeed be insensitive to levels of processing manipulations.

Changes between the modality in which information is first learned and later tested do not significantly affect explicit test performance (Graf, 1994). These changes, however, can significantly reduce performance on implicit memory tests. Some studies (Roediger & Blaxton, 1987; Roediger & Weldon, 1987) even show that changes in the surface features of information between study and test can influence implicit test performance while having minimal effects on explicit memory tests.

## The Manipulation of Attention and Implicit-Explicit Memory Dissociation

Recently, a number of studies have shown that the manipulation of attention during encoding of either visual or auditory information does not affect later implicit memory of the information whereas explicit retention is strongly affected. Many researchers attribute these implicit/explicit memory dissociations following the manipulation of attention to automatic processing of information that is also retrieved without conscious awareness on the implicit memory tests. These claims are, however, made without objective indicators. It is the goal of this dissertation to explore the processes that account for implicit/explicit dissociations following the manipulation of attention during the study of information. The rationale for the current investigation will be fully outlined after the review of literature.

## Conceptual and Operational Definition of Attention

The term "attention" is rarely defined, even though it is used frequently in the cognitive psychology literature. An early definition (Treisman, 1969) viewed attention as the selective aspect of perception and response. For purposes of selection, Treisman suggested that a number of different perceptual "analyzers" provided the individual with a set of mutually exclusive descriptions for a stimulus. She identified four functionally different types of selection that are involved in attention. Selection determines (a) the input that is sent to the analyzers, (b) the particular analyzers used, (c) which tests are made on the target within analyzers, and (d) the output of the analyzer that is stored or used to control responses. Triesman's view of attention assumes that in terms of input, attention restricts perception by selecting which set of sensory data to analyze. This type of attention therefore determines the data we look at and listen to. Attention also determines the dimensions or properties of stimuli to analyze and ignores other dimensions or properties. Attention specifies the complete set of mutually exclusive values between which we discriminate, leaving other sets unanalyzed. In terms of tests that are made on the target, attention selects particular targets or goals of perceptual analysis and particular items we wish to identify, where the items are defined by one or a specified set of critical features. Test selection is said to differ from analyzer selection in that it specifies the desired results of analysis, whereas analyzer selection specifies only the set of possible results between which we will discriminate. Finally, the selected inputs are fully analyzed by the analyzers that also match selected outputs to the appropriate actions. Treisman assumes that there are, however, some limits to the responses that can be made and the information that can be stored because the simultaneous output of perceptual analysis competes for access to limited capacity motor and memory systems. The competition might be between outputs of different analyzers given the same input or between outputs of a single analyzer given different inputs. In contrast, less interference is expected when different analyzers discriminate along dimensions that vary independently. Thus, more interference may occur when one is required to shadow auditory input in one ear and ignore input into the other ear compared to reading and listening to a song.

Posner and Boies (1971) have identified three general senses in which attention is considered. In one sense, attention is considered as alertness. By alertness they mean the ability to develop and maintain an optimal sensitivity to external stimulation. Thus, the ability to perform in long boring tasks could be considered as attention. Attention could also be considered as the ability to select information from one source or one kind, rather than the other. In the third sense, attention relates to the limitation in the information processing capacity. Thus, interference occurs when two operations make competing demands on the limited capacity mechanism. Posner and Boies have suggested that stimuli may be encoded without interference from other signals. The encoded information makes contact with its long term representation without requiring processing capacity. Interference occurs when the mental operations require a response selection or rehearsal of the encoded information.

Treisman's interpretation of attention relates to the second sense identified by Posner and Boies because it refers to instances where a subject may be required to report information from a particular sensory modality or spatial location, or to focus on information of a specific kind (e.g., letters rather than digits). It is assumed that the ability to perform such tasks requires filtering mechanisms to block out or attenuate other inputs that could potentially be selected. Although this conceptualization of attention may be inferred in the studies that have manipulated attention in the investigation of implicit/explicit dissociation, it is never stated explicitly. "Attention" in this dissertation will refer to the selection of a defined set of stimuli for processing by a limited capacity information processing resource.

## Automatic Information Processing and Implicit Memory

Perhaps the most important issue arising from studies to be reviewed next is the claim that implicit memory for unattended information is due to automatic processes at study. Again, the term "automatic" is rarely defined in these statements because many researchers probably assume that the meaning of the term is clear to the reader. Because "automaticity" may be construed in different ways by researchers, the assumption that the meaning of the term is the same to every reader is incorrect.

Posner and Snyder (1975) argued that automatic processes are those that occur without intention, without conscious awareness, and without interfering with the processing of other information. Shiffrin and Schneider (1977) offered a similar view that automatic processes are not hindered by the capacity limitations of short term store or the set of currently activated nodes that are the subset of a large and permanent collection of nodes that constitute memory. According to Shiffrin and Schneider, automatic processes require considerable training to develop and are difficult to modify once they are learned. Shiffrin and Schneider further claimed that once an automatic process is initiated it runs to completion without being hindered by other processes. These ideas were integrated by Hasher and Zacks (1979), who added that automatic processes drain minimal amount of energy from attentional capacity and thereby enable the organism to operate even under circumstances where huge demands may be placed on the attentional capacity. In their view, the sources of automatic processes are both hereditary and experiential (practice). It is assumed that the nervous system is wired to maximize the processing of certain types of information. Thus, minimal experience may be required for the acquisition of some automatic processes. A second source of automatic processes comes through practice. Large amounts of practice under some circumstances will lead to the development of automatic processes. Hasher and Zacks refer to the process of encoding the meaning of words as one of a variety of memory skills that may become automatic through practice.

The general idea from these different views is that automatic processes can develop through practice and that once a specific activity attains a certain level of practice, the process can be carried out without much control by the individual. In contrast, effortful processes limit a person's ability to engage simultaneously in other effortful processes. Although the efficiency of these processes increases with practice, their use is voluntary (Hasher & Zacks, 1979). Shiffrin and Schneider have proposed a similar idea: They view controlled processes as those that are activated through the control and intention of the subject. Shiffrin and Schneider claim that because these processes require active attention, only one activity in a sequence may be controlled without interference.

The views of automaticity discussed in the preceding paragraphs may suggest that processes are either automatic or not automatic (Posner & Snyder, 1975; Shiffrin & Schneider, 1977). It has been suggested that automaticity is a matter of degree and varies in its dependence on spatial allocation of attention (see, e.g., Cohen, Dunbar, & McClelland, 1990; Francolini & Egeth, 1980; Kahneman & Henik, 1981; Kahneman & Treisman, 1984; MacLeod & Dunbar, 1988). A preferable view of automaticity in the framework of this dissertation is Logan's (1988) instance based theory of automatization because it does not assume that automaticity is an all-or-none phenomenon.

Logan conceptualizes automaticity in terms of the acquisition of a domain-specific knowledge base that is acquired through practice on the same items. In the absence of practice the novice learner arrives at the solution to a problem through a time consuming and effortful algorithm. As the learner accumulates enough practice with the solution, however, more memory traces for specific instances of the solutions are laid down. These memory traces can be later retrieved to provide solutions the next instance the same problem is encountered without the learner computing the solution through an algorithm. The retrieval of solutions to the same problems becomes faster with increased practice until the stage is reached where the retrieval of solutions from memory always becomes faster than solutions computed algorithmically. After this stage has been reached, the learner may abandon the algorithm entirely because retrieval of solutions from memory is faster and more efficient. It is at this stage, according to Logan, that performance becomes automatic.

Logan's instance theory of automaticity makes three main assumptions about the mechanisms underlying the gradual transition from algorithmic solutions to memory based retrieval. First, encoding into memory is the obligatory unavoidable consequence of attention. Attention to a stimulus is assumed to be enough to commit it to memory. The stimulus may be remembered well or poorly depending on the conditions of attention, but it will be encoded. A second assumption is that retrieval from memory is the obligatory unavoidable consequence of attention. Attending to a stimulus is sufficient for a retrieval from memory to occur. This retrieval will involve whatever has been associated with the stimulus in the past. Successful retrieval is assumed to depend on how much attention is allocated to a stimulus at the time of encoding. The third assumption is that each encounter with a stimulus is encoded, stored, and retrieved separately. These assumptions of the instance theory of automatization suggest that learning can occur even when it is not the intention of the subject to learn. Attention to an item may be all that is required to encode it into memory but the quality of encoding will depend on the quality and quantity of attention. For example, subjects remember the same items better when they attend to their semantic compared to their physical features (cf. Craik & Tulving, 1975).

According to Logan, when traditional views of automaticity (e.g., Posner & Snyder, 1975) claim that automatic processes are unconscious, they do so from the belief that automatic processes are executed without thinking. Furthermore, this claim may be based on the fact that algorithms may involve a series of steps or stages each of which can be subjected to introspection whereas memory retrieval is a single step process. The instance based theory is able to explain these processes through specifying how we think about solutions to problems through algorithmic procedures, and how we arrive at solutions to problems without thinking because a solution is retrieved from memory. Logan's account of automaticity involves both absolute and relative aspects: absolute because performance may sometimes be based on memory retrieval and relative because performance may sometimes involve an algorithm.

Strayer and Kramer's (1990) view on automaticity is similar to that offered by Logan. For them, automaticity is a knowledge base developed through practice that facilitates the retrieval of past solutions. They suggest that because a number of distinct learning mechanisms are involved in the development of automaticity and the acquisition of skill, it is better to consider task components and not whole tasks as automatic or nonautomatic. It is their view that certain components of a task may become automatic while other components may remain nonautomatic.

## Review of the Literature

Many studies to be reviewed have shown that the manipulation of attention during encoding of visual or auditory information does not affect implicit memory whereas it does affect explicit memory. The prevailing explanation of these dissociations is that the unattended information is processed automatically and retrieved without awareness, whereas explicit retrieval is poor because it requires attentive processing. It is, however, not clear whether this assumption is justified given that the inference about automatic processing of information is based on test outcomes. Because many of these studies are unable to provide objective indicators of a lack of attention to the to-be-ignored information, it may be problematic to assume that the dissociation is due to automatic processing of information. The absence of objective indicators that confirm a lack of attention to the to-be-ignored information or automatic processing of presumably unattended information leaves the resulting dissociations open to two interpretations: (a) that attention is not adequately diverted from the to-be-ignored information by the manipulations, or (b) that although the information is indeed unattended, it is nevertheless processed automatically. This review is aimed at highlighting some of these problems and laying the foundation for the procedures that will be used to address the issues to be raised.

*Auditory Manipulation of Attention*

Tone-monitoring and dichotic listening are the two main classes of auditory attention (divided attention) manipulations used in repetition priming experiments. In tone monitoring tasks, subjects usually detect and report the pitch of tones (high, medium, or low) while simultaneously learning some critical information. It is assumed that the concurrent tone-monitoring task depletes the pool of attention resources available for processing the critical information. Dissociation is shown when performance on an explicit memory test is affected by the manipulation whereas implicit test performance is left intact.

*Tone Monitoring*

Many studies using tone monitoring have reported dissociations in implicit and explicit memory for critical information presented under divided attention conditions (e.g., Isingrini, Vazou, & Leroy, 1993; Parkin & Russo, 1990; Parkin, Reid, & Russo, 1990; Schmitter-Edgecombe, 1996 [See Table 1]). These studies differ in a number of ways, including the kinds of information learned, the structure of study tasks, and the kinds of implicit and explicit measures used. For example, picture completion tests have been studied under divided attention conditions with free recall as the explicit test and savings in picture completion as the implicit test (Parkin & Russo, 1990).

The implicit and explicit memory tests used also differ markedly. Implicit tests that have been employed include category association, perceptual clarification, tachistoscopic identification (Schmitter-

Edgecombe, 1996), picture fragment completion (Parkin & Russo, 1990), or category-exemplar generation (Isingrini et al., 1993). Among the tests used in these experiments are tachistoscopic identification and category-exemplar generation. Explicit memory tests include free recall (Parkin & Russo, 1990), graphemic cued recall and semantic cued recall (Schmitter-Edgecombe, 1996) and word recognition (Parkin et al., 1990).

The essential point, however, is that whereas a measure of implicit memory is unaffected by division of attention, a measure of explicit memory is affected by the manipulation of attention. A study by Gardiner and Parkin (1990) represents a case in point. In this study, subjects in the full attention condition learned a list of words without distraction whereas those in the divided attention group performed a tone monitoring task during study. Tone presentation was at one of two speeds, a slow speed so as not to be too demanding, and one that was double the speed of that in the first and, thus, more demanding. Following the study task, subjects indicated which of 72 studied and unstudied words they recognized from the study phase. For each item identified, subjects indicated whether they "remembered" or "knew" it from the previous study phase. To "remember" was defined as a recognition that evoked some specific recollection from the learning sequence. To "know" was defined as a recognition that failed to evoke any specific conscious recollection from the learning sequence.

"Remember" responses were significantly higher in the undivided attention condition compared to the slow presentation divided attention condition and were lowest in the fast divided attention condition. In contrast, there was no significant effect of study conditions on the "know" responses. These findings were interpreted as showing that the "know" responses were not influenced by the amount of conscious processing resources available at study. According to Gardiner and Parkin (1990), the findings support the claim that "knowing" resembled other forms of implicit memory (cf. Parkin et al. 1990; Parkin & Russo, 1990), whereas "remember" responses were a reflection of elaborate or conceptually driven processes that occurred in an episodic memory system.

Jacoby and associates have used a variation of the tone monitoring task to study divided attention effects on recognition and familiarity of studied information. The divided attention task required that subjects listen for and indicate by key press their detection of a sequence of odd digits while simultaneously reading a list of names. Divided attention hampered the recognition (explicit memory) of studied items while sparing familiarity (implicit memory) (Jacoby, Woloshyn, & Kelley, 1989).

A variation of the paradigm manipulated attention to auditory stimuli with a concurrent visual task (Koriat & Feuerstein, 1976). Subjects in the intentional condition attended to an auditorily presented list of words without distractions whereas those in the incidental learning condition performed a prioritized digit symbol test while listening to the words. Following the list presentation, subjects recalled the words they remembered from the list, and completed a forced choice recognition test. Priming of the items was obtained with a 40 item discrete free association test comprising 20 cue words and 20 filler words. Each of the cue words was associatively related to one word in the list. The frequency with which each of the response words was elicited by its cue had been normed on the responses of 550 students. The cue words were intended to prime or activate the words learned. If the associative word a subject gave to the cue was one of the words learned, it was considered as evidence of priming. Recall was most affected whereas priming was least affected by the different encoding conditions. Ten times as many words were recalled, and twice as many were recognized in the intentional condition compared to the incidental condition. There was no significant difference between the conditions, however, in terms of priming. Koriat and Feuerstein suggested that the results could be considered as consistent with the automatic processing of information in the absence of attention.

That implicit/explicit dissociations are consistently reported in these studies despite the different study materials and implicit and explicit tests used suggests that the effects of attention manipulation are quite reliable. The general conclusion from these studies is that the insensitivity of implicit memory to divided attention is due to the automatic processing of unattended information (Parkin, 1989; Parkin & Russo, 1990; Parkin et al., 1990; Schmitter-Edgecombe, 1996).

Although many of these studies do not define what they mean by attention, the underlying assumption is that the concurrent task depletes the available processing resources. This assumption may be not be justified in all cases. Subjects are able to divide attention between auditory information and visual information presented concurrently (Allport, Antonis, & Reynolds, 1972). Indeed, Allport et al. have shown that recognition memory for visually presented words was not severely affected by a concurrent shadowing task. There was even less effect on the concurrent visually presented pictures. Likewise, the subjects could shadow information while reading and playing difficult piano music. Allport et al. have suggested that complex tasks depend on a number of independent, specialized processors, many of which may be common to other tasks. Task performance is most difficult if the same processors are involved in two tasks simultaneously. By contrast, if there are no common processors involved in the simultaneous performance of a task, concurrent performance is possible without interference. Treisman and Davies (1973) have made similar arguments, remarking that there are marked perceptual limits when two inputs converge on the same analyzing mechanisms whereas divided attention is possible when the two concurrent inputs are in different modalities.

The observations made by Allport, Treisman, and their associates about the division of attention between modalities suggest that this manipulation may not be the most effective procedure for studying attention processes in implicit and explicit memory. If implicit and explicit memory performance depend on different processing mechanisms (e.g., data-driven perceptual implicit tests vs. conceptual explicit tests), there is the possibility that attention to the concurrent tone monitoring task may not interfere with the critical processing resources enough to prevent attentive processing of information later retrieved in the implicit memory tests. Although studies using tone monitoring might show a dissociation, the methodology may be flawed because it is often difficult to ascertain whether the processing of the information is really without attention.

*Dichotic Listening*

Treisman and Davies suggested that a better attention manipulation strategy was one that occurred within the same sensory modality. This idea suggests that dichotic listening procedures may be more suitable for divided attention studies on implicit and explicit memory because the same analyzer is used for processing information from two channels. In fact, some studies have used dichotic listening procedures for the manipulation of attention (see Table 2). In these tasks, subjects shadow information (usually prose) in one ear while ignoring competing critical messages in the other ear. Dissociation is shown when equivalent priming occurs in the unattended and attended conditions whereas explicit memory is affected in the unattended condition. Eich (1984) has indeed reported such a dissociation with a dichotic listening task.

In Eich's study, subjects shadowed prose played in one auditory channel while a series of words containing homophones (e.g., taxi-FARE, movie-REEL) was presented on the other channel. The interpretations of these homophones were biased toward their less common meanings by the other member of the pair. In the ensuing recognition test, subjects indicated whether a word spoken by the experimenter had been presented earlier in the unattended ear. Finally, the subjects spelled a series of words spoken by the examiner. The test items included 16 old homophones presented in the unattended ears during study, 16 new homophones, 8 old nonhomophones and 24 new nonhomophones.

Subjects' recognition of unattended words was poor, suggesting that there was little or no long term retention of the unattended information.

Implicit memory as measured by the probability of spelling a homophone in line with its less common meaning was higher, however, if the item had been previously presented in the unattended channel. Eich argued that spelling operated in the absence of awareness of earlier experiences whereas deliberate or intentional forms of remembering required attention to stimuli and analyses of events. The implicit assumption in Eich's argument is that the processing of the homophones occurred automatically, thus leading to the dissociation observed in the implicit and explicit tests. There is, however, no reason to assume that the information was processed without attention even though the concurrent tasks used the same modality. Indeed, in a follow-up study, Eich showed that when attention was focused solely on the homophones during study, the explicit recognition and priming in terms of homophone spelling were significantly higher compared to that obtained under conditions of divided attention. This outcome suggests that priming is reduced following the manipulation of attention.

Anooshian (1989) has presented findings that support the view that the allocation of attention to information determines the amount of implicit and explicit memory. In her study, subjects in the unattended condition shadowed a story in the attended ear while 16 short phrases containing homophones (e.g., "a fairy TALE") were repeatedly presented to the unattended ear. The phrases were designed to bias interpretation of the homophones toward their least frequent meanings. Subjects in the full attention condition were presented with the same homophones in the form of questions (e.g., "Would you rather hear a fairy TALE or a sad story?").

The subjects answered each question as it was presented over headphones to both ears. The ensuing recognition test required subjects to identify the words played during the study phase. Subjects also performed either of two implicit tests: spelling homophones (old, new, and new nonhomophones) or free association to each word read by the examiner with a word of their choice as quickly as possible. Performance in both the implicit and explicit tests was significantly higher in the full attention compared to the divided attention condition.

These results reported by Eich and Anooshian suggest that implicit/explicit memory dissociation using within-subject manipulations may not be the best way to determine the effects of attention manipulation on memory processes. The results also suggest that although some automatic processing of unattended information may occur, the priming from these processes is lower compared to priming where full attention is given to the critical information. If so, this challenges the supposed insensitivity of attention manipulation to implicit memory. The crucial issue is that even if unattended information is supposedly processed automatically, none of the studies reviewed so far provide any a priori indicators of this process, choosing instead to justify their interpretations on the basis of test outcomes. The presumed automatic processing of information in the unattended condition can be supported only when priming is equivalent for the attended and unattended conditions but explicit retrieval is different for the groups. Similar claims cannot be made, however, when the manipulation of attention during study affects both implicit and explicit memory of the unattended condition.

Although not couched in terms of explicit-implicit dissociation Wilson's (1979, Experiment 2) study is one more that shows the differential effects of the manipulation of attention on explicit recognition and affective preference of studied information. The study determined whether subjects would prefer certain auditory stimuli over others following mere exposure to the stimuli. The author presented crit' al information to subjects using a modified dichotic listening procedure. Subjects listened to a series of tones presented in the unattended channel while listening to prose simultaneously presented in the attended channel. Subjects were also given a typewritten copy of the prose that contained a number of deliberate errors on each line. They were instructed to repeat aloud each sentence in the message as soon as they heard it and cross out the words in the written text that did not correspond to the words heard in the attended ear. According to the author, this manipulation abolished recognition and brought it to chance level in a subsequent memory test. There was, however, significantly higher affective preference for the old unattended tones even when they were judged as new. The authors concluded that the positive feelings for previously encountered stimuli did not dependent on a conscious knowing or perception that the object was familiar. To state this in explicit-implicit terminology, the manipulation of attention with a dichotic listening task reduced explicit recognition while leaving affective preference for the information. The author attributed the results of this dissociative effect to processes that "are not at the level of conscious awareness" (p. 819). The author makes a claim for which there are no objective indicators.

*Summary of Section*

The foregoing review has considered variables that produce differential effects in implicit and explicit memory tests. The concurrent monitoring of tones with the learning of critical visual information, or the shadowing of prose while critical information is simultaneously presented in an unattended ear has no adverse effects on implicit retention of information. Explicit retention is, however, strongly influenced by these manipulations. These effects are quite robust considering that a wide range of materials is studied and a wide range of explicit and implicit memory tests is used. The general conclusion from many of these studies is that unattended information is processed automatically and retrieved without conscious intention or awareness in implicit memory tests, whereas failure to process the information attentively results in poor explicit retrieval. It is argued here, however, that the attribution of the dissociative results to automatic processes cannot be justified because there are no objective indicators to show that the presumed unattended information is actually unattended. Indeed, one study (Anooshian, 1989) has shown that implicit and explicit memory may be equally affected by attention under some circumstances.

*Visual Manipulation of Attention*

Dissociations between implicit and explicit memory also occur following the manipulation of attention to information in the visual sensory modality. The two main classes of procedures are filtering, and a combination of brief presentation of information with a concurrent task.

Filtering procedures present multiple stimuli to subjects usually on a monitor. Subjects are instructed to process and report the critical information and ignore the irrelevant competing information. This procedure can be conceived as the visual analog of the dichotic listening task. In one sense, a subject can be instructed to select one item, say a word, from an array of different words for processing. In another sense, the instruction may require that subjects pay attention to an attribute, say ink color of the selected word. A case of filtering as applied in the second sense is that of the Stroop color-word paradigm.

The brief presentation of visual information on the other hand exposes the critical material for only short durations to subjects. These brief exposures make it difficult for subjects to consciously apprehend the information. Although subjects may fail to consciously apprehend the information, they may nevertheless show memory in later implicit memory tests whereas their explicit recognition of the information may be poor.

*Filtering*

Studies that come under this rubric (see Table 3) manipulate attention within the visual modality, and thereby avoid some of the problems that may plague manipulations that divide attention between modalities. Filtering procedures vary in a number of ways. Thus, whereas subjects may be instructed to select one of two words and ignore the other in some studies (e.g., Merikle & Reingold, 1991; Wolters & Phaf, 1990), the flanking procedure (see Wolford & Morrison, 1980) asks subjects to focus attention on digits that are presented at both ends of a single word on a monitor, and ignore the word itself (Hawley & Johnston, 1991; Kinoshita, 1995). In the flanking procedure, subjects are asked either to verify whether the digits are of the same type (odd or even) or to add and report the sum of the digits. A variation of the flanking procedure asks subjects to verify whether the answer provided to the addition of two numbers is correct. The word to be ignored is presented before the answer (e.g., Kellogg, Newcombe, Kammer, & Schmitt, 1993).

There are also variations in the implicit and explicit measures used with these visual manipulations of attention. Despite the different memory tests, the consensus is that visual manipulation of attention does not affect implicit memory whereas it does hamper the explicit retrieval of unattended information (Kellogg et al., 1993; Kinoshita, 1995; Merikle & Reingold, 1991; Wolters & Phaf, 1990). These studies, again, assume that the performance of the specific task required by the experimenter prevents subjects from processing the to-be-ignored information. Thus, when implicit retention of the presumed unattended information is revealed in an implicit memory test, the outcome is attributed to the unconscious or automatic processing of the unattended information (see Merikle & Reingold, 1991; Wolters & Phaf, 1990). Others claim that the manipulation of attention during study fails to hamper implicit memory (Kellogg et al., 1993) or that implicit/explicit memory dissociation occurs for stimuli that are not consciously apprehended (Kinoshita, 1995). The presumed unconscious processing of unattended information is again claimed as the reason for the dissociation in implicit and explicit memory, although none of these studies provide any indicators that attention was indeed diverted from processing the critical information.

*The Stroop Color-Word Paradigm*

In the original paradigm (see Stroop, 1935) subjects quickly read color names printed in black and color names where the colors of the print and the words were different. Colors used were red, blue, green, brown, and purple. In Experiment 1, reading time showed a 2.3 s average difference between the time it took to read 100 color names printed in different colors from that named by the words, and reading of the same names printed in black. This difference was not statistically significant. In Experiment 2, however, there was a significant 47 s increase in response time when subjects named the color of the ink in which color words were printed, where the color of the ink and the words were different, compared to naming the colors of solid squares. According to Stroop, it was reasonable to conclude that the difference in the speed of reading names of colors and naming colors could be accounted for by the difference in training in the two activities. Whereas the word stimulus has been associated with the response to read, the color stimulus has been associated with various responses including "to admire," "to name," "to reach for," "to avoid," etc.

The interference of the printed incongruent color names in the color naming response is now generally known as the "Stroop effect." The phenomenon is robust and has been reported in many studies (see Dyer, 1973; MacLeod, 1991, for reviews). Modifications of the paradigm involve the use of words that do not name the colors of words. These modified paradigms have been used in several settings including the study of memory.

Grand and Segal (1966, Experiment 4) may have been the first to use the Stroop color-word paradigm for the study of memory processes (see Table 3). Although they did not couch their memory terms as implicit and explicit, their results are similar to those obtained with other attention manipulation strategies. In their study, one group of subjects named the colors of 15 word associates (e.g., DOCTOR-NURSE, SOLDIER-ARMY) printed in red, green, yellow, and blue whereas another group crossed out vowels in the same sets of associates presented in black. Following their respective tasks, subjects completed a word association (implicit) test in which the experimenters presented words to which the subjects supplied associative words. The subjects also completed a free recall (explicit) test following the word association test. On the word association test, there was significantly higher priming of words in the color naming condition compared to the vowel crossing condition. Free recall, in contrast, was significantly higher following vowel crossing compared to the color naming task. Grand and Segal suggested that registration of the words was not in full awareness because of the incidental nature of the task. The assumption that unattended words were processed automatically was again made following the results of this study, even though there was no objective evidence that the color named words were registered without full awareness.

While the research for this dissertation was well under way, two papers that manipulated attention to critical verbal information with the

Stroop color word paradigm were published. Important findings from these papers are reviewed here. Although these are only a few, a consensus appears to be emerging that manipulation of attention with the modified Stroop task does not affect implicit retention of information whereas explicit retention is severely affected (Szymanski & MacLeod, 1996; Wippich, 1995). Despite the common task used, slight variations exist in the structure as well as the implicit and explicit tests used in these two studies.

In Wippich's (1995) study, subjects responded to a list of words presented in different colors; red, green, yellow, and blue. One group of subjects read the words whereas the other group named ink colors of the words. Subsequent to the study phase, some subjects from each group responded to a list of word stems with the first word that came to mind (implicit test). Others completed the stems with specific words they could remember from the study phase (explicit test). There was significantly higher implicit memory for words that were read compared to color-named although priming for words that were color-named was also reliable. Likewise, there was greater explicit cued recall for words that were read. In a follow-up experiment, Wippich presented two words, one above fixation and the other below fixation on a computer monitor. Some subjects read or color-named words above or below fixation whereas others read or color-named both words. The ensuing implicit word stem completion test produced significant priming for words when ink colors at test were the same as at study (see Wippich, 1995). This outcome applied to both words that were read and words that were color named, and was true regardless of whether subjects had responded to both words or to only one during the study phase. Priming of words presented either above fixation or below fixation on the monitor but were neither read nor color-named tended to be negative, however, when the colors were changed between study and test. Wippich concluded that color cues could function as an independent basis for priming even if previous lexical access had not occurred.

Attention manipulation with the Stroop task in Wippich's study appeared to have had less negative impact on implicit memory when the colors of unattended words at test were the same as at study. Explicit memory was more significantly reduced when the words were ignored. Like many others, Wippich claimed that "the results described represented an existence proof - measures of implicit memory may reveal unconscious influences of the past [p. 259]." It is uncertain what the basis of Wippich's proof of unconscious influences of the past is: There was no indicator of unconscious processing of the words. This claim, like many made before, can only be made on the basis of the test outcome. As already argued, this post hoc reasoning cannot be justified.

A paper published recently (Szymanski & MacLeod, 1996) used manipulations that presented the opportunity for the researchers to obtain some indicators for automatic processing of words in the Stroop color-word paradigm. In this study, forty subjects studied a list of regular words in a Stroop color-word paradigm. The words were printed in red, blue, green, or yellow. Subjects received two blocks of 36 words each with different instructions. Subjects read words aloud in one block, and named the colors of words, plus the colors of 12 rows of XXs, in another block. Following the study task, half of the subjects completed a lexical decision task, whereas the remaining half completed an explicit word recognition test. The yes/no recognition test required subjects to decide whether specific test words had been presented in the study phase. Recognition performance indicated that words that were read in the study phase were better recognized compared to those whose ink colors were named. Thus, explicit retrieval was better if the words had been attended at the time of study. In sharp contrast, there was no significant priming difference between word reading and color naming in the implicit lexical decision task. Both showed reliable and equivalent priming.

According to Szymanski and MacLeod, processing of words occurred after the subjects had simply been exposed to their physical characteristics. These processes presumably enabled the words to be accessed later without the requirement of awareness. Szymanski and MacLeod stated that their "study provided no evidence that initial attention conferred any benefit on subsequent implicit memory performance (p. 173)." This statement suggests that whatever processes produced priming occurred automatically. They also suggested that simply being exposed to the physical characteristic of words at study engaged processes that were later reenacted at test without awareness. Although Szymanski and MacLeod were careful to include a control for the color naming response, they were unable to obtain any indication of automatic processing of the words, since the time for color naming words did not differ significantly from that for color naming XXs. Indeed, the mean time for XX color naming ($M$ = 799 ms) was longer compared to that for color naming words ($M$ = 782). This absence of the Stroop effect is quite unusual and might have been due to the presentation format, as the authors observed. Although naming the incongruent ink colors of color words produce greater interference, there is evidence that naming the colors of ordinary words also produces some interference (see Klein, 1964). The absence of the Stroop effect in Szymanski and MacLeod's study could not, however, enable one to demonstrate the processing of words following mere exposure to their physical characteristics. This argument can only be made by reference to the test outcome.

*Summary of Section*

The manipulation of attention with filtering or the Stroop task has produced dissociations between implicit and explicit memory in the studies reviewed (see Table 4). The advantage of these manipulations is that they are within the same visual modality. The study tasks as well as the implicit and explicit memory tests used are different. That implicit/explicit memory dissociations occur despite these differences suggest that the insensitivity of implicit memory to the manipulation of attention during study is a robust phenomenon. These studies are, however, plagued by the problem of post hoc explanations of findings. The studies do not provide indicators of automatic information processing during the manipulation of attention and this makes it difficult to be certain whether the presumed insensitivity of implicit memory is due to automatic processing or attentive processing of the presumed ignored information.

*Brief Visual Presentation of Stimuli*

Studies that control stimulus awareness with brief presentation (see Kunst-Wilson & Zajonc, 1980; Mandler, Nakamura, & Van Zandt, 1987), nevertheless, have provided useful information about the effect of brief exposure on measures that reflect implicit (e.g., the affective preference of information that is not consciously perceived) and explicit retention of information. These studies may lend support to the view that the mere encounter with stimuli leads to their automatic processing and is revealed in implicit memory tests whereas explicit recognition of the information is usually poor.

Some of these studies have combined brief presentation with concurrent shadowing of information as in divided attention manipulations, or with filtering. An example of a study in the first category is one by Seamon, Brody, and Kauff (1983, Experiment 3). Subjects studied irregular polygons under full attention whereas an equal number of subjects viewed these stimuli while shadowing a taped sequence of words. Each stimulus item was presented for 2 ms. Following the presentation of stimuli, subjects indicated their preference of stimulus items in a forced choice presentation of item pairs, followed by a recognition test. One of the items in the test pair had been briefly presented whereas the other had not. There was greater affective preference and better recognition of presented items in the nonshadowed compared to the divided attention condition. In contrast, whereas affective preference was significantly high for presented items in the divided attention condition, recognition of the items was significantly poorer compared to the nonshadowed condition.

The manipulation of attention at study, therefore, affected explicit memory on the recognition test while sparing implicit memory as revealed in the affective preference test. These results are in conformity with the majority of studies that show implicit memory to be insensitive to the manipulation of attention whereas explicit memory is severely affected by the manipulation of attention during study. Seamon et al. (1983) interpreted their results as suggesting that subjects may require less time or encoding capacity to form a preference for target items compared to recognition of these items. The implicit assumption is that processing of information about the items might have occurred without attention. The assumption cannot, however, be justified on the basis of the results.

The issue of whether subjects consciously apprehend briefly presented information is a controversial topic that is tangential to the current goal. The interested reader will find more information on this issue in other sources (see Merikle & Reingold, 1992). For the present purposes, there is no objective measure to suggest that the processing of information in the absence of awareness leads to the affective preference of the one stimulus item over the other.

Contrary to the presumed inability of attention manipulation to affect implicit and explicit memory, Hawley and Johnston (1991, Experiment 2) have presented findings that strongly challenge the prevailing opinion. They used the flanking procedure to manipulate attention at three levels. In the full attention condition, subjects concentrated exclusively on the words. In the divided attention group, subjects divided their attention equally between the words and the digits task, reporting equally often the sum of the two digits or the words. In the unattended condition, subjects ignored the words, concentrated exclusively on the digits, and reported the sums. Ninety subjects studied either the words, digits, or both as they were presented in the center of the monitor. The words were masked after 33 ms or 67 ms. Following the study phase, subjects completed a perceptual memory (implicit) test followed by a yes/no recognition (explicit) test. For the perceptual memory test, a word masked with 300 dots was presented at the center of the monitor for subjects to name. The identity of the word was progressively revealed through randomly removing dots from the mask at the rate of one dot per 20 ms. Subjects were asked to name the word before all the dots were removed in 6 s.

The results showed that recognition memory increased with level of attention and duration of exposure. The greater the attention given to the words at study, the greater the recognition memory. Despite the duration of word exposure at study, perceptual memory was at baseline in the unattended condition. Perceptual memory was slightly above chance for the items exposed for longer duration in the divided attention condition. Subjects in the full attention condition showed significant perceptual memory for words presented for 33 ms or 67 ms. The results of this study indicated that both implicit and explicit memory were attenuated with the division of attention, and facilitated by the focusing of attention.

According to Hawley and Johnston, perceptual memory and recognition memory are similarly affected by manipulations of levels of attention and awareness at study. Neither perceptual memory nor recognition memory appeared to be established for words that achieved relatively minimal levels of awareness. Hawley and Johnston concluded that their results discredit the view that a substantial amount of encoding occurs for stimuli that do not attain consciousness and undergo effortful processing. The absence of priming in the divided attention conditions relative to the attended condition in this study is important because it undermines the presumption that reliable priming following the manipulation of attention is due to automatic processing of unattended information. If the brief presentation of stimuli prevents the occurrence of reliable priming on later implicit memory tests, the results raise the prospect that perhaps in some studies where the manipulation of attention does not affect implicit memory, some aspects of the presumed unattended information are nevertheless processed attentively and retrieved in later implicit tests.

*Summary of Section*

Briefly presented stimuli may not be consciously perceived. The studies reviewed (see Table 4) suggest, however, that information that is not consciously apprehended may, nevertheless, be revealed in an implicit test whereas explicit retrieval may be impaired. These findings suggest, therefore, that the mere presentation of information can lead to automatic processing. Two reviewed studies have combined the brief presentation of stimuli with divided attention or filtering tasks. The results from these studies are equivocal on the issue of the effect of attention on briefly presented stimuli. Whereas Seamon and his associates have suggested that briefly presented information does not affect implicit memory despite affecting explicit memory, Hawley and Johnston have cast doubt on the presumed automatic processing of information in the absence of conscious awareness.

*Anesthesia and Sleep*

The review concludes with a brief mention of studies that have examined implicit/explicit memory dissociations with anesthesia and sleep. Although these manipulations are not in terms of stimuli selection, results from such studies are, nevertheless, related to the current discussion. The ability of stimuli that presumably are unattended, and of which the subjects are unaware, to influence performance on implicit memory tests may lend credibility to the view that attention to critical information is not a prerequisite for priming.

Recent work in this area includes studies reported by Kihlstrom, Schacter, Cork, Hurt, and Behr (1990). This study showed that patients retained information presented while anesthetized. Implicit memory was not affected by anesthesia whereas explicit memory was abolished by the manipulation. The retention of information despite the absence of consciousness is a remarkable demonstration that suggests that lack of conscious awareness of information does not adversely affect implicit memory. Although similar findings have been reported (see Ghoneim, Block, Sum Ping, Ali, & Hoffman, 1990) there is no uniform consensus on the issue of implicit/explicit memory dissociation following the administration of anesthesia. Some studies (Polster, Gray, McCarthy, & Park, 1990; Winograd, Sebel, Goldman, & Clifton, 1990) have failed to show implicit memory for information presented while the subjects were anesthetized. Likewise, subjects fail to show implicit and explicit memory for information presented during sleep (Wood, Bootzin, Kihlstrom, & Schacter, 1992).

*Summary and Evaluation of Attention Manipulation*
*and Implicit-Explicit Memory Dissociation*

Many of the studies reviewed in the foregoing (see Tables 1-4) have explored the effects of attention manipulation either in the visual or auditory modality on implicit and explicit retention of information. Although the methods used for manipulating attention, the materials studied, and the implicit and explicit memory tests used differ between studies, there is a strong consensus that the manipulation of attention during encoding of visual or auditory information does not affect implicit memory whereas it affects explicit memory. The prevailing assumption for these dissociative effects is that the unattended information is processed automatically and retrieved without awareness, whereas explicit retrieval is poor because it requires attentive processing. It is not clear whether this assumption is justified given that it is made after the fact. Indeed, these studies do not offer any objective indicators to support the assumed processing of unattended information other than the results of the tests. Objective a priori indicators of automatic information processing can, however, be demonstrated in the classical Stroop effect.

In the classical Stroop paradigm, color names cause considerable delays in the naming of ink colors, if the ink colors are incompatible with the color names. A comparison of the reaction time to the incompatible ink colors of color words and ink colors of a neutral set of stimuli (e.g., XXs) gives an indication of automatic information processing. Although automatic processing of ordinary words may not be as strong as neutral words, neutral words are nevertheless automatically processed in the color naming task (Regan, 1978). Thus, a comparison of the reaction time for naming neutral strings of XXs to that of naming neutral words can provide objective indication of automatic processing of words.

The three reviewed studies that have used the modified Stroop color-word paradigm, however, have not been successful in settling the issue of automatic information processing as the reason for implicit/explicit dissociation. Although Grand and Segal (1966) likely pioneered the use of the modified Stroop paradigm in the study of priming, they did not directly address the issue of dissociations between implicit and explicit memory. Wippich's (1995) study did not present performance data in the study phases of his experiments. Indeed, the paradigm used could not allow the assessment of processing of to-be-ignored information because there was no baseline to enable that assessment. Syzmanski and MacLeod (1996) used a better strategy in that the inclusion of baseline material for the color naming task offered the chance to determine automatic processing of unattended information. Unfortunately, their inability to obtain the Stroop effect could not enable them to indicate, a priori, the kind of processes that produced the dissociative effect on implicit and explicit memory.

The review has also considered studies that have used briefly presented visual information for the study of implicit and explicit memory.

Although the intention in these studies is the manipulation of stimulus awareness/unawareness, some have shown that memory for brief visual presentation of information can be revealed in implicit memory tests whereas explicit recognition is poor. Results from these studies support the general finding that implicit memory is not affected by awareness of information whereas explicit retrieval is affected. These implicit/explicit memory dissociations lend some credibility to the view that information is processed automatically without the need for attention. Hawley and Johnston have, however, presented some data that challenge the prevailing assumption that implicit memory is not affected by the manipulation of attention at study whereas explicit memory is affected.

## Statement of the Problem

The studies reviewed so far attribute implicit/explicit memory dissociation following the manipulation of attention at study to automatic processing of unattended information that is also retrieved without intention in the completion of implicit memory tests. Justification of this claim by reference to the data following implicit and explicit memory tests is based on a circular argument. These studies provide no a priori objective measures of automatic processing of information during study.

The foregoing review has shown that it is possible for some supposedly unattended information to be processed attentively. Indeed, some studies have shown that the manipulation of attention equally influences implicit and explicit memory (Anooshian, 1989; Eich, 1984; Hawley & Johnston, 1991). These findings suggest that the presumed automatic processing of unattended information that subsequently produces implicit/explicit dissociations needs to be critically reexamined. One problem highlighted in this review is that the concepts "attention" and "automaticity" are not explicitly defined by many researchers. This lack of explicit definitions makes it difficult to determine the precise manipulations at study or the processes that account for the implicit/explicit dissociations observed. More important, however, is the pervasive post hoc assumption made in many of these studies that the memory dissociations are due to automatic processing of information. This assumption needs to be properly tested for it to be viable.

The goal of this dissertation is to present a methodology for assessing the presumed automatic information processing during the manipulation of attention at study. The satisfaction of this criterion will provide a strong basis on which to determine whether implicit/explicit memory dissociation following study can indeed be attributed to automatic processes.

## Theoretical Explanations of the Stroop Effect

Since Stroop's publication of his findings, different theoretical interpretations have been suggested for the interference observed in naming the ink colors in which words are printed. Klein (1964) suggested that the meanings of words were automatically processed to some degree in the standard Stroop task. He compared interference for nonsense syllables, rare English words, common English words not closely associated with color names, words related to colors (e.g., lemon, grass, etc.), different words of the same response class (e.g., tan, gray, etc.), and the standard, incongruent color words. Nonsense syllables generated the least interference, with interference increasing progressively with rare words, common non-color words, color related words, and color words. Klein's data suggested that interference was increased as the relation to color was increased. These results have been replicated in normal and autistic children (Eskes, Bryson, & McCormick, 1990). The automatic processing of the words is supported by findings that the locus of interference is after a word has been processed and not during the processing. In other words, the interference of words in the color naming response occurs at the output or response end, not the input or reading end (Dalrymple-Alford & Azkoul, 1972).

A recent review (MacLeod, 1991) has considered the main theoretical interpretations for the Stroop effect. Two of these will be considered briefly. The automaticity hypothesis (e.g., Posner & Snyder, 1975) views the interference as occurring because words are obligatorily read even when the required response is the naming of colors. Presumably, the automatic reading of words is due to the extensive practice people have with reading compared to naming the colors of items. Although a strong all-or-none automaticity may fail to explain all aspects of the Stroop effect (see Kahneman & Henik, 1981), a view of automaticity that allows for attention allocation strategies to exert some influence can explain the interference effect. When attention is focused on the color it is not easy to reject the word (Kahneman & Henik, 1981; Kahneman & Treisman, 1984).

The Parallel Distributed Processing (PDP) account of the Stroop effect (Cohen et al., 1990) incorporates aspects of automaticity and the relative speed of processing. The relative speed of processing theory supposes that the Stroop effect occurs because responses are simultaneously initiated for words and colors during the color-naming task. This competition occurs presumably because word reading that is the faster response interferes with the slow color-naming response. The competition leads to the delay in response to the colors because the faster reading response wins out against the slower color-naming response (see Dyer, 1973).

The basic idea of PDP is that processing occurs in the system through activation that moves along pathways of different strengths. The outcome of this process is represented as a pattern of activation over the units. Processing occurs by the spread of activation along connections both within modules and between modules. In naming the ink color of a printed word, for example, activation occurs in two pathways, one for the ink color information and the other for the word information. These share a response mechanism. Each of these pathways will have a set of input units each of which is connected to every intermediate unit. Each intermediate unit also connects to all output units. The processing of information begins with the input units and feeds forward to the response units one of which will eventually accrue sufficient information to exceed threshold and produce a response. The response occurs when a particular unit's output threshold is exceeded. A unit's response strength is the ratio of its activation to total activation. The dual activation in the two pathways, even when the response is expected in only one, indicates the extensive processing that occurs in the pathway that does not control the eventual response.

The general idea from the automaticity and PDP models is that even when the task requires the processing of the colors of words, there is simultaneous processing of the word. Klein's (1964) study also presents important information suggesting that stimulus items are processed according to how meaningful they are. The automatic reading of words even when color naming is required makes the Stroop task ideal for the study of attention processes (see MacLeod, 1992) and likewise memory processes.

## The Modified Stroop Color-Word Task

The modified Stroop color word paradigm provides a basis from which to explore the processing and dissociation mechanisms in implicit and explicit memory following attention manipulation. The task to be used in this dissertation will involve the simultaneous presentation of words and relatively neutral baseline (XX) stimuli printed in different colors on a computer monitor. The presentation of stimuli will be brief (300 ms) so as to limit the availability of critical words for processing by subjects whose attention is to be taken away from the words with the color naming tasks. Because the subjects cannot predict the locations in which each stimulus item will be presented prior to its onset, they must first select a subset of the presented item for further processing, and actively ignore the interfering items. The paradigm, thus, combines aspects of the Stroop color-word paradigm with the filtering paradigm (Kahneman, Treisman, & Burkell, 1983; Treisman, Kahneman, & Burkell, 1983; Kahneman & Treisman, 1984).

As discussed in the foregoing, attention to the colors in which words are printed leads to the obligatory processing of the word. Interference in color naming of words compared to neutral strings of XXs will therefore suggest that the to-be-ignored words are, nevertheless, automatically processed. A comparison of the response times for color naming words to color naming XXs will give an indication of the obligatory processing of words in the color naming task. Because the strings of XXs will appear in distant locations from the words, attention to the XXs will address the condition where it may be assumed that the words are indeed ignored. Attention will thus be manipulated in two different senses; (a) in terms of the location where information (words or XXs) is presented and (b) in terms of the attribute of the stimulus item (word or color).

To summarize, attention to the XXs that appear simultaneously at distant locations from the words will serve the purposes of providing a baseline for the color naming response, and a condition in which it may be assumed that the words are indeed ignored. The color naming task will represent the condition in which automatic word processing can be observed. An indication of this process will be obtained by comparing response latencies for color naming XXs to color naming words. The reading condition will represent that in which full attention is given to the words. It is expected that the reading of the words will be faster compared to the naming of colors of the words or colors of a neutral string of XXs (cf. Dyer, 1973; Fraisse, 1969). Naming ink colors of relatively neutral strings of XXs is expected to be faster, however, compared to naming the ink colors of the ordinary words to be used in this study (Klein, 1964; Regan, 1978). The slower naming of ink colors of the words compared to that of relatively neutral strings of XXs will be taken as indication of the automatic processing of the words by the subjects.

This setup offers the opportunity for assessing the presumed automatic processing of unattended information that produces implicit/explicit memory dissociations. The paradigm is similar in some respects to that used by Szymanski and MacLeod (1996) and Wippich (1995, Experiment 2) in its use of the Stroop color word paradigm. The combination of the Stroop task with filtering in which critical information may have to be rejected, however, sets this paradigm apart.

The between-subject manipulations of attention during study not only approximates the design employed in many of the studies reviewed. More importantly, the manipulation of attention between groups avoids the possible carryover effects when subjects perform different tasks on the same stimulus items. When manipulations are within-subjects, it is difficult to isolate the specific processing strategies that may account for differences in test outcomes after subjects have processed several dimensions of the same items. Furthermore, some of the studies reviewed (e.g., Anooshian, 1989; Eich, 1984) suggest that results from within-subject manipulations do not provide a complete picture about the effects of manipulation of attention during study on later implicit and explicit memory tests. Eich showed that a between-subject manipulation provided a stronger effect of the manipulation of attention during study on implicit and explicit memory compared to a within-subject manipulation, a finding that was replicated by Anooshian.

Green (1996) has recently suggested that different results may be obtained depending on whether the independent variable is manipulated within-subjects or between-subjects. Using the Brown-Peterson short term memory distractor paradigm, Green found the traditional rapid memory loss for letters presented to subjects when retention interval was manipulated within-subjects but not between subjects. To avoid the possible complications with carryover effects and differences in strategies that may prevent the emergence of a complete picture in a within-subject manipulation therefore, it was deemed more expedient to manipulate attention between-subjects in this investigation.

# General Method

*Subjects*

All subjects were volunteers from introductory psychology courses at Dalhousie University, each of whom earned a credit point for participating in the experiments. All subjects had normal or corrected-to-normal vision and were neither color-blind nor dysl      oy self report. Subjects were randomly assigned to conditions and were tested individually.

*Apparatus*

All stimuli were displayed on a Macintosh color monitor and were driven by a Macintosh LC 475 8/160 ..omputer. The stimuli were generated with ThinkPascal 4. The latency between stimulus onset and subject's voice response was recorded by activating a voice-operated relay accurate to 2 ms. The fixation point in the center of the monitor appeared 43 cm from the top of the table. Words presented above or below fixation point ranged in length from five to 10 letters and were written in 24 point Helvetica font at a height of 7 mm. At a viewing distance of 50 cm from where subjects placed their chins in a chin rest, the words subtended 0.8° vertically and between 3.4° and 6.8° horizontally. Each row of eight XXs printed in the same font as the words subtended 5.7° horizontally. The distance from the center of the fixation cross to the nearest contour of the letters or XXs was 3.5 cm respectively. The corresponding visual angles were 4.0° above and below the fixation point respectively. The entire visual display subtended

10.8° vertically. Trials were recorded as invalid and discarded from analyses if the subject made an error in reading a word or naming a color. Reaction times that exceeded 1.5 s were also excluded from analyses as outliers.

### *Materials*

Stimulus words were selected from a list normed for word frequency (Thorndike & Lorge, 1944). Target items (words or XXs) were printed in one of six colors (red, blue, green, orange, purple, or yellow) with an equal number of words or XXs printed in each of the six colors.

In all experiments, two stimuli were presented simultaneously above and below fixation in different colors. Half of target items appeared above fixation whereas the other half appeared below fixation. Furthermore, half of each set of 10 target items written in one color appeared above fixation while the rest appeared below fixation. A completely randomized list of the stimuli was presented to each subject.

#### *Test Stimuli:*

Two lists of word fragments with unique solutions generated from 25 students were used. These lists were balanced for completion difficulty with List A having a mean frequency of 11 occurences per million whereas List B had a mean frequency of 10 words per million (Thorndike & Lorge, 1944). Word stems were made by first obtaining the baseline completion rate for a list of words from 30 students, none of whom participated in these experiments. Words with zero completion rate were matched for number of letters, syllables, and frequency. List A words had a mean frequency of 16 occurrences per million words whereas List B words had a mean frequency of 15 occurrences per million words (Thorndike & Lorge, 1944). Of the balanced lists of 60 words each, List A items were presented at study whereas List B items were used for baseline measurement (see Appendix A and B).

Sixty words were used for study presentation. The nonpresented matched list was used as baseline words. For the implicit test, each subject was tested on one of two sets of 45 word fragments or word stems each. Each 45 word set contained fragments or stems of 15 words presented on the monitor (Presented), 15 matched words (Nonpresented), and 15 filler words. For the explicit cued recall test, each subject was tested on one of two sets of 45 word fragments or stems each. Each set contained 15 words presented on the monitor (Presented), 15 matched words (Nonpresented), and 15 filler words. Nonpresented items were words of equal completion difficulty and frequency as those presented on the monitor, whereas filler items were word fragments that were relatively easy to solve.

*Procedure*

*Study Tasks:*

Subjects were randomly assigned to attention conditions and instructed to either read a word or name its ink color quickly and accurately as items appeared on the monitor. In the Read Word condition, subjects read the word on the screen. Subjects in the Name Word Color condition named the ink colors in which the letters of the words were printed, whereas those in the Name XX Color condition named the ink colors in which the XXs were printed. All subjects were informed that the target item (words or XX pattern) would appear randomly either above or below the fixation point and that they would be surrounded by a black rectangular box to facilitate target localization. The items were presented against a white background.

Subjects were given 10 practice trials to familiarize them with the procedure. Stimulus presentation began with a fixation point presented in the center of the screen for a 1 s duration. Each stimulus was presented for 300 ms, after which a blank screen appeared (see Figure 1 for a schematic presentation of a trial). Subjects' reaction times to the stimuli were recorded with the voice-operated relay microphone and the experimenter checked the responses for accuracy from an adjacent room.

*Testing*

Subjects completed word fragments or word stems under implicit or explicit instructions immediately following stimulus presentation. To minimize carryover effects, the implicit memory test was always administered first, followed immediately by the explicit memory test. In the implicit memory test, subjects were instructed to quickly complete the test cue (word stem or word fragment) with the first word that came to mind. In the explicit memory test, they only completed the test cues with the words they recognized from the preceding presentation of stimuli.

The total time allowed for word fragment or word stem completion in the implicit and explicit memory tests following stimulus presentation was 10 min, respectively. Subjects used a cover sheet to prevent them from looking ahead to new items and were instructed not to go back to an item once it had been passed.

A modified version of the retrieval intentionality criterion (RIC) procedure (Schacter, Bowers, & Booker, 1989) was employed to control for carryover effect in the completion of implicit and explicit memory tests. The procedure requires that subjects be provided with the same cues for retrieval on both the implicit and explicit memory tasks. For implicit memory tests the instruction requires subjects to perform the task without thinking back to the previous study episode, whereas the explicit memory test requires that subjects make reference to the study episode. Furthermore, the procedure proposes that the experimental manipulation be one that will selectively affect performance on one of these tests but not the other. The RIC procedure assumes that because the experimenter maintains the same cues and only varies the retrieval instructions, the resulting differential performance on the tests can be firmly attributed to the different instructions. Whereas the explicit memory test emphasizes the intentional use of information from the prior study episode, implicit memory test does not emphasize this requirement. Such a procedure, it is argued, will enable the deduction of ideas about the nature of implicit and explicit memory.

Although stochastic independence has been reported with such a procedure (Tulving, Schacter, & Stark, 1982; Hayman & Tulving, 1989) the idea of maintaining the same external cues for retrieval in both implicit and explicit memory tests, nevertheless, presents a problem when testing within subjects. Even though a subject may not intend to retrieve information from a prior study episode for the completion of a nominal implicit memory test, the provision of the same cues for implicit and explicit tests tempts the subject to do so. The chances for contamination of retrieval strategies are greater when the implicit memory test is completed following the explicit memory test in which the subject is deliberately encouraged to use explicit retrieval strategies. Even when the implicit memory test is administered first, there is still the likelihood that the nominally explicit memory test that follows will, indeed, be completed on the basis of information intentionally retrieved from the prior study episode plus that from the immediately preceding implicit test based on unintentional retrieval. In other words, performance on the putatively explicit test could, theoretically, be a reflection of both intentionally retrieved information and information not intentionally retrieved.

To avoid this problem, some modifications to the RIC were introduced. First, carryover effects were eliminated by testing for half of the studied items with an implicit memory test and the other half with an explicit memory test. Second, implicit memory tests were always administered first followed by explicit memory tests. The nature of cues remained the same between tests, but the specific cue items used in the implicit memory tests were different from those used in the explicit memory. The RIC procedure maintains the advantage of revealing implicit and explicit test performance. It is, however, less vulnerable to contamination of retrieval strategies. Whereas this modification by no means eliminates the likelihood of contamination of strategies, it does, at least, minimize a potential problem.

During debriefing sessions, subjects were consistently asked to describe the strategies adopted during the study task and testing. They were specifically asked whether they noticed any relation between the implicit test and words presented during study, and whether their completion of the implicit and explicit test items was influenced by the intentional retrieval of information from the study phase. Only a handful admitted to observing the study task-testing relations and using a common strategy for completing both tests. Data from these subjects were subsequently deleted from the database and not included in any of the analyses reported here. Indeed, many subjects in the Name Word Color and Name XX Color conditions consistently remarked that because they ignored the words during study, they could not complete the explicit memory test. They were all encouraged to make the effort and they all did.

Correlation coefficients between performance on implicit and explicit tests were also examined. The absence of significant correlation between these tests indicated the absence of mutual retrieval strategies in the completion of these tasks.

*Data Analyses*

Reaction time (RT) and accuracy (% correct) of study task performance were analyzed by analysis of variance (ANOVA). Post hoc analyses used the Newman Keuls procedure. The notation for these analyses is of the type A < B = C. For example, if analysis showed that RTs in word reading and color naming were similar but both were statistically slower than XX color naming, the relations were stated as follows: Name XX Color < Name Word Color = Read Word.

Second, separate data analyses were performed for implicit and explicit tests. For implicit tests, a mixed factorial analysis of variance was used in all analyses. The study task was the between-subject factor whereas performance on presented (Target) and nonpresented (Baseline) words (either % completion rate or RT) formed the repeated measures factor. A priming score was determined by subtracting the proportion correct or RT for Baseline words from Target words. For explicit tests, a mixed factorial analysis was done as well, with study tasks as between-subjects factor and test performance on presented (Hits) and nonpresented (False Alarms) words. Corrected cued recall was calculated by subtracting % False Alarms from % Hits. The priming and corrected cued recall scores were separately analyzed first for their deviation from zero, followed by a one way ANOVA with Study task as between-subject factor and subsequent post hoc tests. Finally, correlations were determined between the implicit and explicit test measures. The significance level for all tests was set at $p < .05$.

## Experiment 1

The experiment was designed to address the issue of automatic information processing supposed to be accountable for implicit/explicit memory dissociation in many of the studies reviewed. The foregoing review has shown that response delays in color naming words relative to a neutral string of items (e.g., XXs) suggest that the words are nevertheless processed obligatorily. Although the interference from color words is significantly greater compared to ordinary words, ordinary words nevertheless also produce some interference in the color naming task (see Klein, 1964; Regan, 1979). The presence of this interference provides an objective measure of automaticity in word reading. As stated earlier, a comparison of the response times for color naming words to color naming XXs that are presented simultaneously with the words (but at different locations on the visual display) would give an indication of the automatic processing of words in the color naming task. Furthermore, attention to the XXs was expected to address the condition where it may be assumed that the words are indeed ignored. Because attention presumably is not a prerequisite for priming, the processing of XXs should not affect performance on later implicit memory test for the words presented.

Thus, if unattended information was automatically processed and retrieved in implicit memory tests, equal levels of priming for the critical words presented in this modified Stroop color-word paradigm was expected when subjects either read the words, named their ink colors, or the ink colors of XXs. In contrast, because elaborate processing is necessary for explicit retrieval of information, it was expected that word reading would produce better explicit memory compared to word or XX color naming.

## Method

*Subjects*

Seventy-nine undergraduates participated in the experiment. See General Methods for description of materials.

## Results

*Study Task Performance*

Data from one subject who claimed to have observed a relation between the stimulus presentation and the implicit memory test were excluded from the analyses. Thus, the results reported are based on data from 78 subjects. The mean reaction times (RTs) and accuracies (% correct) in response to the presented words were each analyzed with a one way analysis of variance (ANOVA) with Study Task as the independent variable with three levels (Read Word vs. Name Word Color vs. Name XX Color). The summary of performance data is presented in Table 5. A total of 14 RT data points (0.3%) was classified as outliers. A breakdown of these outliers is as follows: Nine for Read Word, 3 for Name Word Color and 2 for Name XX Color conditions respectively.

Analysis of the RTs revealed a significant effect of Study Task [$F(2, 75) = 15.1$, $MSe = 6414.2$, $p < .0001$]. Posthoc analyses of this effect revealed that Name XX Color < Name Word Color = Read Word. The slower RTs for naming word colors compared to naming XX colors suggested that the words interfered with the color naming responses. There was, therefore, a Stroop interference effect in ink color naming. Analyses of performance accuracies revealed no significant differences between the groups ($F < 1$).

*Implicit Test*

Fragment completion rates were analyzed in a 3 (Study Task: Read Word vs. Name Word Color vs. Name XX Color) X 2 (Item Type: Presented vs. Nonpresented) mixed factorial ANOVA. See Table 6 for a summary. The analyses revealed a significant main effect of Study Task [$F(2, 75) = 9.4$, $MSe = .02$, $p < .0001$], Item Type [$F(1, 75) = 45.16$, $MSe = .009$, $p < .0001$], and a significant Study Task X Item Type interaction [$F(2, 75) = 12.82$, $p < .0001$]. Posthoc analysis of the interaction showed that completion of Targets > Baseline in only the Read Word condition.

*Priming*

Priming was determined by subtracting the proportion of completed Nonpresented words from that of Presented words for the different Study tasks (see Table 6). The scores were first analyzed separately for the different conditions to determine the deviation of each score from zero. Analysis of the Read Word condition showed that the priming score was significantly different from zero [$t(25) = 7.2$, $p < .0001$]. Analyses for the other conditions revealed priming scores were marginally significantly different from zero in the Name Word Color [$t(25) = 1.91$, $p = .07$], and

Name XX Color [$t(25) = 1.92, p = .06$] conditions.

The overall effect of Study Task on priming was determined using a one-way ANOVA. This analysis revealed a significant main effect of Study Task [$F(2, 75) = 12.8, MSe = .019, p < .0001$]. Post hoc analyses of this effect revealed that priming in Read Word > Name Word Color = Name XX Color.

*Explicit Test*

A similar procedure to that in the implicit test was used in the analysis of the proportion of fragments completed in the explicit test. The design was, again, a 3 (Study Task: Read Word vs. Name Word Color vs. Name XX Color) X 2 (Item Type: Presented vs. Nonpresented) mixed factorial ANOVA. The analyses revealed a significant main effect of Study Task [$F(2, 75) = 12.4, MSe = .03, p < .0001$], no significant effect of Item Type ($F < 2$), but a significant Study Task X Item Type interaction [$F(2, 75) = 14.66, MSe = .016, p < .0001$]. Posthoc analysis of the interaction revealed that Hits > False Alarms only in the Read Word condition.

*Corrected Cued Recall*

The subtraction of proportion of completed Nonpresented words from those of Presented words for the different Study Tasks gave the corrected cued recall score (see Table 6). Separate analysis showed that cued recall in the Read Word condition was significantly different from zero [$t(25) = 5.35, p < .0001$]. Cued recall in the Name Word Color [$t(25) = -2.3, p < .03$] was significantly below zero, indicating negative cued recall. Likewise, cued recall in the Name XX Color [$t(25) = -0.42$, $p = .06$] was below zero, although this was nonsignificant.

A one-way ANOVA on corrected cued recall revealed a significant main effect of Study Task [$F(2, 75) = 14.6$, $MSe = .02$, $p < .0001$]. Post hoc analyses of this effect revealed that corrected cued recall in Read Word > Name Word Color = Name XX Color.

*Priming-Corrected Cued Recall Correlation*

To determine whether the same retrieval strategies were used in the performance of implicit and explicit memory tests, correlations between priming and cued recall were determined for the Study Tasks. There was no significant correlation between priming and cued recall in either the Read Word [$r(26) = .15$, $p > .05$] or the Name XX Color [$r(26) = .11$, $p > .05$] conditions. A significant negative correlation between priming and cued recall was, however, observed in the Name Word Color condition [$r(26) = -.38$, $p < .05$].

## Discussion

The reading of target words in this experiment produced significant priming. In contrast, naming colors of words or XXs only produced marginally significant priming. As expected, word reading produced significant cued recall compared to word and XX color naming. In fact, cued recall in the color naming condition fell significantly below the baseline.

The performance data confirmed that the typical Stroop effect was obtained in that the mean RT in the Name Word color condition was longer compared to that in the Name XX Color condition. This interference supports the idea that some aspect of the words was automatically processed in the Name Word Color condition, and that the relatively more practiced automatic reading response interfered with the color naming response (MacLeod & Dunbar, 1988). The performance data indicated that subjects performed their respective tasks with similar mean performance accuracy suggesting that the differences in the speed at which the different tasks were performed were not due to speed-accuracy tradeoff. Although word reading was expected to be faster than either color-naming words or the relatively neutral XXs (cf. Fraisse, 1969), this expectation was not confirmed. Indeed, word reading did not differ significantly from color-naming the words. The unexpected slow word reading was probably due to the relatively low frequency of the words (see Appendix A) that required subjects to take a longer time to translate print to pronunciation. Furthermore, it is likely the selection and response to the words was accompanied by a filtering cost (see Kahneman et al., 1983; Treisman et al., 1983). Filtering cost generally refers to the time taken by subjects to focus attention on the critical stimulus item and block out irrelevant items from further processing. This cost is observed when it takes a longer time to read a word presented simultaneously with an irrelevant stimulus item (e.g., XXs) compared to reading the same word presented alone (see Kahneman et al., 1983).

Priming in the Read Word condition was similar to typical levels reported in previous studies (see e.g., Rajaram & Roediger, 1993; Roediger et al., 1992; Weldon, 1991; Wippich, 1995). The marginal levels of priming in the Name Word Color and Name XX Color groups is surprising, however, considering the results from many of the studies reviewed. These studies report reliable priming even when attention is not focused on the critical information (see e.g., Kellogg et al., 1993; Kinoshita, 1995). The marginal priming in the Name Word and XX Color conditions suggests that automatic processing of ignored information does not necessarily lead to implicit memory as many studies have suggested. Indeed, these results suggest that without attention to critical information implicit memory is as poor as explicit memory. These results echo those reported by Hawley and Johnston (1991) who also showed that both implicit and explicit memory for briefly presented words were eliminated with the manipulation of attention at study.

*The Feature Integration Model and Object Files*

The interpretation of these results will be guided by ideas from the feature integration theory and transfer appropriate processing approach to memory. The Feature Integration Model (Treisman & Gelade, 1980) suggests that a key feature of the information processing either in the auditory or visual channel, is early extraction of feature information. In the processing of visual information, for example, features are registered early, automatically, and in parallel across the visual field. The scene is initially coded along a number of separate dimensions such as color, orientation, shape, spatial frequency, brightness, direction of movement, etc. The combination of these separate representations to form a specific object in this complex display requires focal attention, however. Focal attention acts as the "glue" that integrates the initially separable features into a unitary object. It is after focal attention has occurred that the compound object is perceived and stored. According to Treisman and Gelade (1980), these features cannot be related to each other without focal attention.

Treisman and her associates (see Kahneman et al., 1983; Treisman & Kahneman, 1984, Kahneman et al., 1992) have further explained that the end product of perceptual processing of any visual scene is a set of object files, each of which contains information about objects in the scene. The object files are initially addressed with reference to their location at any particular time and not by any features or identifying labels. Further information about particular objects is collected and stored in the respective files. Information stored in the object files can be matched to stored representation to identify or classify the object, although this need not be the case. A file is kept open as long as its object is in view. This file may be discarded, however, shortly thereafter. Visual objects are hierarchically organized according to features, and one of these may be dominant i the parsing of the scene at any one instance. Treisman and her associates assume that the object files are set up in terms of the features into which a scene is parsed. These features are determined by the controlled allocation of attention or by the automatic effect of bottom-up constraints and grouping factors. Thus, if attention allocation is on a specific feature, say the color of an object, that feature becomes more prominent whereas other aspects, say the size or shape, may be pushed into the perceptual background. The content of the object file will contain information of the aspect of the object to which attention is devoted.

It is assumed that when attention is directed to an object, it facilitates the production of all responses associated to separable properties of the attended object and that attentional competition only occurs between rather than within object files. The greater the amount of attention allocated to an object, the richer the amount of information that may be accrued as record in the object file. The update of information accrues continuously as more and more attention is allocated to an object until the stage where the object is identified by matching it to specifications in long term perceptual memory. This recognition occurs through the sensory description in the object file being compared to stored representations of known objects. It is claimed that when a match is found, the identification of the object is recorded in the file together with other characteristic information predicting the likely behavior of the object and the appropriate affective and cognitive responses that it should evoke. The identification of the object allows for the retrieval and storage in the file of a name or category, and of previously learned facts that relate to the object.

The essential idea from the Feature Integration Theory reviewed is that information processing occurs through the extraction of features and their integration into specific objects. Feature extraction occurs automatically. These features cannot, however, constitute an object without attention. Attention plays the role of integrating the extracted features into an object that can be identified, recognized or labeled.

*Interpretation of Results Within the Feature Integration Model*

The processes of selective attention and information processing for the study tasks determined the kinds of object files created for the words presented. The Feature Integration Theory would suggest that the processing of the words in the Name XX Color condition was at the level of their salient features. Because the words appeared at distant locations from the selected XXs, and were presumably not attended, perceptual analysis was probably at the feature level. In the Name Word Color condition, facilitation would have occurred for responses associated with the separable properties of the words (i.e., the colors, word shapes, etc.) when they became the focus of attention (Kahneman & Henik, 1981). Because attentional competition does not occur within object files, all responses associated with the attended words would have been facilitated. Although other aspects of the words including the word shapes and meanings (Klein, 1964) may have been activated during the color-naming task, the colors of the words probably gained more prominence as the records in the object files since the subjects responded to the colors. Word reading created strong records because performance of that task facilitated the processing of all aspects of the words including the colors, shapes, syllables, and meanings.

In summary, although attention was not focused primarily on the words in either the Name Word Color or Name XX Color conditions, some salient aspects of the words were, nevertheless, processed. It is not yet clear which aspects were processed. The marginal levels of repetition priming in these conditions could suggest, however, that the test used for assessing priming did not present task processing demands that could reactivate records of the words created in the Name Word Color and Name XX Color conditions. As the transfer appropriate processing approach generally suggests (e.g., Roediger, 1990b) retrieval of information in a memory test benefits to the extent processing operations during encoding are reenacted at test.

The Feature Integration Theory would predict that words that were read were fully processed and identified. The process facilitated the retrieval and storage in the file of a name or category, previously learned facts that relate to the words, including the possible evocation of affective and other cognitive responses. The records of words read would have been created with both their perceptual and conceptual characteristics and encoded with their context into episodic memory. These records would have been strong and robust because the words were apparently fully attended and processed. The resulting records could be retrieved with the cues provided on the explicit test. In contrast, word color naming or XX color naming prevented the elaborate processing of the words, thus creating weaker records not retrievable in the explicit cued recall test. The cued recall results, thus, confirmed the hypothesis. Failure to respond to the critical words in the display was expected to result in poor explicit memory for the words, and it did. Indeed, there was no explicit memory for the words when attention was diverted to the colors of the words or XXs during study.

Many studies show poor explicit retention in the absence of attention to critical information (see e.g., Eich, 1984; Parkin & Russo, 1990). Because attention in the Name Word Color and Name XX Color conditions was not primarily focused on the words, the records of features extracted were weak and could not be elaborated. Thus, the recall of these words could not be adequately cued with the fragments. There was, however, a high false alarm rate, especially in the Read Word and Name Word Color conditions. Indeed, there was a significantly higher completion of nonpresented compared to presented words in the Name Word Color condition. It is not clear why this occurred, however, although the overall pattern of cued recall in the implicit memory test suggests that diversion of attention from the words severely affected explicit retrieval. This pattern of results has been reported by Hawley and Johnston (1991).

The absence of significant correlation between priming and corrected cued recall in the Read Word and Name Word Color conditions implies that the subjects were not using the same strategies for the completion of implicit and explicit tests. Although the significance of the inverse relation between priming and corrected cued recall in the Name Word Color condition is unclear, it still suggests there was no overlap in strategies between the completion in the implicit and explicit tests. These results strengthen the assumption that implicit and explicit tests differed in terms of retrieval intentionality strategies.

In summary, the manipulation of attention with the Stroop color-word paradigm significantly reduced implicit memory for the unattended words and did not produce dissociations between implicit and explicit memory. Indeed, priming in the word fragment test, after the attention of subjects had been directed to the colors of words and XXs, was marginal. Similar results were obtained in the explicit memory test. Only attention to the words during study produced significant priming and cued recall. These results are in stark contrast to many of the studies reviewed in which the manipulation of attention does not affect implicit memory the way it affects explicit memory. Contrary to the prevailing view, automatic processing of words in the Name Word Color condition did not lead to normal priming in the word fragment completion test. The results from this experiment support those reported by Hawley and Johnston (1991).

Experiment 2

Two questions that grew out of Experiment 1 were (a) whether the marginal levels of priming in the Name Word Color and Name XX Color conditions could be attributed to the type of implicit memory test used, and (b) whether the results could generalize to other implicit tests. These questions were pertinent because using identical manipulations of attention with the modified Stroop color word paradigm, Wippich (1995) obtained significant priming in the color naming condition with a word stem completion test.

Roediger et al. (1992) considered the characteristics of word fragments and stems that could produce differential outcomes even when experimental variables were held constant. Word fragment completion tests generally have only one or two solutions compared to multiple possible solutions in word stem completion tests. The word fragment test is generally slow and difficult to complete and appears to demand more effort from subjects who are often unable to complete many of the items. In contrast, word stem completion tests present the first three letters of a word as cues for the completion of a word. The completion rates are high since these stems often supply the cues to at least 10 or more words. Furthermore, responses on this test tend to be very fast and the task itself is relatively easy to complete with subjects completing most of the items. Words used for word fragment completion are characteristically long with very low frequency whereas those used for word stem completion are shorter and with higher frequency. Also, priming effects in word stem completion tests drop to baseline in a few hours (Graf & Mandler, 1984) whereas they persist for longer periods in word fragment completion tests (Komatsu & Ohta, 1984; Roediger & Blaxton, 1987; Sloman, Hayman, Ohta, Law, & Tulving, 1988; Tulving et al., 1982).

Although these differences would suggest that test outcomes with the word fragment and word stem completion tests could be different, some studies have shown similar effects with the two tests. For example, Weldon, Roediger, and Challis (1989) have reported similar effects of experimental variables in the completion of word stem and word fragment tests. Their study showed that after subjects had studied a mixed list of words and pictures under identical conditions, greater priming was obtained for studied words compared to pictures in both word fragment and word stem completion tests. This finding prompted the authors to remark that both tasks engaged similar perceptual or lexical retrieval processes. Other studies (see Roediger et al., 1992; Rajaram & Roediger, 1993) have shown that when experimental variables like levels of processing are held constant, word stem and word fragment completion tests produce the same amount of priming (but see Witherspoon & Moscovitch, 1989 for some contradictory findings).

Given these reported similarities between word fragment completion and word stem completion tests, it is not clear why priming was practically absent in the color naming condition in this experiment while it was quite reliable in Wippich's study. The purpose for Experiment 2 was to examine the generalizability of the results in Experiment 1 using a word stem completion test.

## Method

### *Subjects and Apparatus*

A new group of 92 undergraduates participated in the experiment.

### *Materials and Procedure*

The materials were a new set of 60 words different from those used in Experiment 1. See General Method for details of the procedure.

## Results

### *Study Task Performance*

Data from two subjects who used explicit retrieval strategies for completing the implicit memory test were excluded from the analyses, thus leaving the data for 90 subjects. The mean reaction times (RTs) and accuracies (% correct) in response to the presented words were each analyzed with a one-way analysis of variance (ANOVA) with Study Task as the independent variable with three levels (Read Word vs. Name Word Color vs. Name XX Color). The summary of performance data is presented in Table 7. A total of 9 RT data points (0.16%) was classified as outliers. A breakdown of the outliers is as follows: Six for Read Word, 3 for Name Word Color and none for Name XX Color conditions respectively.

Analysis of the RTs revealed a significant effect of Study Task [$F(2, 87) = 35.57$, $MSe = 6280.8$, $p < .0001$]. Posthoc analyses of this effect revealed the same pattern as seen in Experiment 1, i. e., Name XX Color <

Name Word Color = Read Word. Analyses of performance accuracies revealed no significant differences between the groups ($F < 1$).

*Implicit Memory Test*

Word stem completion rates were analyzed in a 3 (Study Task: Read Word vs. Name Word Color vs. Name XX Color) X 2 (Item Type: Presented vs. Nonpresented) mixed factorial ANOVA. See Table 8 for a summary. The analyses revealed a significant main effect of Study Task [$F(2, 87) = 22.69$, $MSe = .008$, $p < .0001$], Item Type [$F(1, 87) = 73.95$, $MSe = .006$, $p < .0001$], and a significant Study Task X Item Type interaction [$F(2, 87) = 18.77$, $p < .0001$]. Posthoc analysis of the interaction showed that completion of Target > Baseline words occurred only in the Read Word condition.

*Priming*

Priming was determined by subtracting the proportion of Nonpresented words from those of Presented words for the different Study tasks (see Table 8). The scores were first analyzed separately for the different conditions to determine the deviation of each score from zero. Analysis of the Read Word condition showed that the priming score was significantly different from zero [$t(29) = 8.1$, $p < .0001$]. Analyses of data in the Name Word Color [$t(29) = 3.0$, $p < .005$] and Name XX Color [$t(29) = 2.82$, $p < .008$] conditions also revealed priming scores that were significantly different from zero.

The overall effect of Study Task on priming was determined using a one-way ANOVA. This analysis revealed a significant main effect of Study Task [$F(2, 87) = 18.77$, $MSe = .01$, $p < .0001$]. Post hoc analyses of this effect revealed that priming in Read Word > Name Word Color = Name XX Color.

*Explicit Test*

A 3 (Study Task: Read Word vs. Name Word Color vs. Name XX Color) X 2 (Item Type: Presented vs. Nonpresented) mixed factorial ANOVA revealed a significant main effect of Study Task [$F(2, 87) = 37.4$, $MSe = .004$, $p < .0001$], Item Type [$F(1, 87) = 61.3$, $MSe = .005$, $p < .0001$], and a significant Study Task X Item Type interaction [$F(2, 87) = 20.62$, $p < .0001$]. Posthoc analysis revealed that Hits > False Alarms only in the Read Word condition.

*Corrected Cued Recall*

The subtraction of the proportion of completed Nonpresented words from those of Presented words for the different Study tasks gave the corrected cued recall score (see Table 8). Separate analysis showed that corrected cued recall in the Read Word condition was significantly different from zero [$t(29) = 7.59$, $p < .0001$]. Corrected cued recall in the Name Word Color condition [$t(29) = 2.23$, $p < .03$] was also significantly different from zero, likewise that in the Name XX Color condition [$t(29) = 2.45$, $p < .02$].

A one-way ANOVA on corrected cued recall revealed a significant ma'n effect of Study Task [$F(2, 87) = 20.62$, $MSe = .009$, $p < .0001$]. Post hoc analyses of this effect revealed that corrected cued recall in Read Word > Name Word Color = Name XX Color.

*Priming-Corrected Cued Recall Correlation*

There was no significant correlation between the priming and corrected cued recall scores in either the Read Word [$r(30) = .03$, $p = .85$], Name Word Color [$r(30) = .21$, $p = .24$], or Name XX Color [$r(30) = .18$, $p = .32$] conditions.

## Discussion

There was significant priming using word stem completion in all conditions in Experiment 2 although priming in the Name Word and Name XX Color conditions was significantly smaller compared to the Read Word condition. Cued recall was also significant in all the conditions, although it was significantly smaller in the color naming conditions compared to the reading condition.

Task performance data, again, indicated that the Stroop interference effect occurred in this experiment. The absence of significant differences in performance accuracy suggests that differences in the speed of processing in the different study conditions were not due to speed-accuracy tradeoff. It is again conjectured that the significant delay in word reading compared to color-naming was due to the relatively low frequency of the words and filtering cost (see Discussion in Experiment 1).

The results of Experiment 2 showed a similar pattern to that obtained in Experiment 1 despite the small but significant priming obtained in the Name Word Color and Name XX Color conditions. Indeed, a cross-experiment (Experiment 1 vs. Experiment 2) analysis of variance of priming and cued recall failed to show significant interaction effects of Experiment on either measure. Although priming was significantly different from baseline in the Name Word and Name XX Color conditions, it was substantially reduced compared to priming in the Read Word condition. Thus, the failure to obtain normal priming with the word fragment completion test in Experiment 1 was also seen with the word stem completion test.

The pattern of cued recall in Experiment 2 also remained similar to that seen in Experiment 1. The smaller but significant priming and cued recall results in Experiment 2 may have been due to less variability in the completion of word stems compared to word fragments in Experiments 1.

As in Experiment 1, the failure to obtain equivalent priming to that in the Read Word condition priming following evidence of automatic word processing in the Name Word Color condition is again surprising. The results are also in marked contrast to those reported by Wippich who used a similar design and a similar implicit memory test and reported robust priming in the color naming condition when the colors of presented words were retained for the word stem completion test. The reinstatement of colors for presented words at test is one possible reason for the discrepancies between the present results, in which the colors of presented words were changed at test, and those of Wippich. Wippich showed that priming diminished significantly for both word reading and color naming conditions when colors of presented words were changed between study and test.

The failure to obtain robust priming for words appearing on the monitor when subjects named the colors of XXs is also unclear. Some aspects of the words would have been processed automatically in the course of target selection (Treisman & Gelade, 1980; Kahneman & Treisman, 1984) and were expected to be retrieved in the completion of the implicit memory test. The relatively poor priming when attention was not primarily focused on the words suggests that the presumed insensitivity of priming to attention manipulation at study may not be that simple. It is remarkable that despite evidence suggesting automatic processing of the words during the color naming response, priming was relatively poor compared to that in the Read Word condition. Indeed, priming in the Name Word Color condition was not significantly different from that obtained for color naming XXs. These results, like those obtained in Experiment 1, suggest that normal priming may not necessarily occur following automatic processing of information. Indeed, the relatively poor levels of priming in two implicit memory tests suggest that the diversion of attention with the color naming tasks reliably reduced implicit memory for the words. These results suggest that focal attention to critical information may be required for normal priming if implicit memory for words presented in the modified Stroop color-word paradigm is assessed with word stem and word fragment completion tests. As priming in the Read Word condition showed, attentive processing of the words produced normal priming, typical of that reported in other studies (see e.g., Rajaram & Roediger, 1993).

Cued recall in the Name Word Color and Name XX Color conditions was significantly lower than that in the Read Word condition. This outcome is not surprising since many studies show that explicit memory for unattended information is poor (see for example, Hawley & Johnson, 1991; Kellogg, et al. 1993). The absence of significant correlations between priming and cued recall in any of the conditions may be tentatively interpreted as suggesting the absence of deliberate attempts by the subjects to complete the implicit test with explicit retrieval strategies.

Experiment 3

As the results from Experiments 1 and 2 show, the puzzling question remained of why robust priming was not obtained in the Name Word Color condition even when there was evidence that the words in the Name Word Color were processed. The rationale for Experiment 3 was to explore the possible reasons for this reduced priming for words in the Name Word Color condition.

A possible explanation was sought in the instructions that guided the selection and processing of items in the word reading and color naming tasks. Treisman (1969) has suggested that a number of different perceptual "analyzers" provide a set of mutually exclusive descriptions for a stimulus. When subjects were instructed to read the words, it was assumed that the selection of stimulus items was guided by shape analyzers. Selection of items in the color naming conditions was assumed to be guided by color analyzers because the subjects were instructed to respond to ink colors and ignore the words. According to Treisman, for subjects to perform such a task, say read words, subjects must use shape analyzers and reject the color analyzers whereas those in the color naming conditions must use color analyzers and reject shape analyzers. Treisman claims that the output of these analyzers may be stored in memory and used to control overt responses.

Although the interfering effects of words in the color naming condition suggest that the subjects failed to completely reject the irrelevant analyzer, they nevertheless overtly responded to the colors and not the shapes of the words. It is possible, therefore, that the color naming task was primarily guided by color analyzers, leaving the shapes of the constituent letters of the words relatively unprocessed. Assuming this was the case, this relative processing difference may not have provided adequate memory traces for letter shapes needed for later priming effects. This difference would explain the remarkable absence of priming on tests that cued memory with fragments or stems of words, each of which required memory of missing letters to complete.

To explore the plausibility of differential use of color vs. shape analyzers, priming for unattended words was examined when shape or color analyzers were in use. Some studies suggest that unattended items exert considerable interference on the processing of attended items when these are at the same level of processing in a visual display (Briand, 1993, 1994; Paquet & Merikle, 1988), suggesting that they could be processed by the shape analyzers used for reading the attended words. In contrast, unattended words may not be processed if color analyzers are being used for processing the words at the attended location. If the use of differential shape vs. color analyzers is responsible for the differences in priming in the Read Word and Name Word Color conditions, then it was expected that priming for the unattended words would be obtained in the Read Word condition but not in the Name Word Color condition.

## Method

*Subjects*

Eighty-one new undergraduates participated in this experiment.

*Materials*

The two lists of 60 words used in Experiment 2 were presented to subjects. Each subject was presented with a completely randomized version of one of the two lists. In a departure from earlier experiments, words were presented in pairs; one above and one below fixation. These words were printed in one of six colors; red, blue, green, orange, purple, and yellow, with five words in each color. The pairs did not appear simultaneously in the same color, and target words that were either read or color named were again surrounded by a rectangular box to facilitate target localization.

Counterbalancing in the implicit and explicit tests was achieved by making the presented and attended words from the alternative list the nonpresented baseline or distractor words for stems in the presented list. Similar procedures were used to achieve counterbalancing for presented/ignored words in the implicit memory and explicit tests.

Two sets of word stems were used in the implicit test whereas the other two sets were used for the explicit test. For the implicit memory test, the first set of word stems assessed implicit memory for presented and attended words. The set comprised word stems from 15 of the presented/attended words, 15 matched nonpresented words (i.e., words presented and attended by subjects who studied the second list of words), and 15 easy-to-complete nonpresented stems of filler words. The second word stem test assessed implicit memory for the presented/ignored words. These stems were made from 15 presented/ignored words, 15 matched nonpresented words (i.e., words presented but ignored by subjects who studied the second list), and 15 nonpresented stems of filler words.

Similar to the construction of the set of stems for the implicit memory test, the explicit memory test comprised word stems from the remaining 15 presented/attended words, 15 matched nonpresented words (i.e., words presented and attended words from the second list), and 15 easy nonpresented filler words. The final set of word stems assessed explicit memory for the presented/ignored items. These stems were made from the remaining 15 presented/ignored words, 15 matched nonpresented words (i.e., words presented but ignored by subjects who studied the second list), and 15 easy stems of nonpresented filler words.

*Procedure*

The study task only had the Read Word and Name Word Color condition. At test, subjects completed four sets of 45 word stems each.

## Results

*Study Task Performance*

Data from one subject were excluded from analysis because the subject admitted to deliberately completing the implicit memory test with words presented during the stimulus presentation phase of the experiment. The results are thus based on data from 80 subjects. The mean reaction times (RTs) and accuracies (% correct) in response to the presented words were each analyzed with one way ANOVA with Study Task as the independent variable with two levels (Read Word vs. Name Word Color).

The summary of performance data is presented in Table 9. Four RT data points (0.16%) classified as outliers were produced in the Read Word condition only. The overall analysis of RTs failed to reveal significant differences between word reading and ink color naming ($F < 2$). There was a significant difference, however, between accuracy in word reading and ink color naming [$F(1, 78) = 29.4$, $MSe = 7.47$, $p < .0001$]. The absence of color naming of neutral items to serve as control in this experiment precludes inferences about the Stroop interference effect in the Name Word Color condition.

*Implicit Memory Test*

Data in the implicit test were analyzed according to a 2 (Study Task: Read Word vs. Name Word Color) X 2 (Item Type: Presented vs. Nonpresented) X 2 (Instruction: Words attended vs. Words ignored) mixed factorial ANOVA.

The analyses revealed a significant main effect of Study Task [$F(1, 78) = 10.95$, $MSe = .01$, $p < .001$], Item Type [$F(2, 156) = 195.0$, $MSe = .003$, $p < .0001$], and Instruction [$F(1, 78) = 186.9$, $MSe = .009$, $p < .0001$]. There were also significant Study Task X Item Type [$F(2, 156) = 9.0$, $p < .0001$], Study Task X Instruction [$F(1, 78) = 13.9$, $p < .0001$], Item Type X Instruction [$F(2, 156) = 113.4$, $MSe = 0.8$, $p < .0001$], and Study Task X Item Type X Instruction [$F(2, 156) = 17.4$, $p < .0001$] interactions. Posthoc analyses of the significant three way interaction revealed that for attended words, Target > Baseline in both Study Tasks. In contrast, for ignored words Target < Baseline in the Read Word condition whereas Target = Baseline in the Name Word Color condition.

*Priming*

Tables 10 A and B present a summary of priming scores for attended and ignored words respectively. Priming of attended words in the Read Word and Name Word Color conditions was significantly different from zero [$t(39) = 12.2$, $p < .0001$] and [$t(39) = 10.0$, $p < .0001$] respectively. The priming score for ignored words in the Read Word condition was also significantly different from zero [$t(39) = -2.2$, $p < .03$], whereas priming of ignored words in the Name Word Color condition was not significantly different from zero [$t(39) = -1.6$, $p = 0.1$].

The overall effect of Study Task on priming was determined with a one-way ANOVA. Separate analyses were done for priming of attended, and ignored words (see Table 10 A, B). Analyses revealed that priming was significantly higher in the Read Word condition compared to the Name Word Color condition for attended words [$F(1, 78) = 12.65$, $MSe = .011$, $p < .01$]. There was no significant effect of Study Task on priming for ignored words ($F < 1$).

*Explicit Memory Test*

Following the format used in the analyses of the implicit memory test data, the explicit cued recall data were analyzed with a 2 (Study Task: Read Word vs. Name Word Color) X 2 (Item Type: Presented vs. Nonpresented) X 2 (Instruction: Words attended vs. Words ignored) mixed factorial ANOVA.

Data analyses revealed a significant main effect of Study Task [$F(1, 78) = 68.98$, $MSe = .004$, $p < .0001$], Item Type [$F(2, 156) = 134.0$, $MSe = .001$, $p < .0001$] and Instruction [$F(1, 78) = 146.0$, $MSe = .004$, $p < .0001$]. There were also significant Study Task X Item Type [$F(2, 156) = 60.8$, $p < .0001$], Study Task X Instruction [$F(1, 78) = 68.4$, $p < .0001$], Item Type X Instruction [$F(2, 156) = 122.18$, $MSe = .001$, $p < .0001$], and Study Task X Item Type X Instruction [$F(2, 156) = 58.8$, $p < .0001$] interactions. Posthoc analyses of the significant three way interaction revealed that for attended words, Hits > False Alarms in both Study Tasks. For ignored words, Hits = False Alarms for both Study Tasks.

*Corrected Cued Recall*

Corrected cued recall of attended words in the Read Word condition was significantly different from zero [$t(39) = 11.5$, $p < .0001$] whereas corrected cued recall for ignored words in the same condition was not significantly different from zero [$t(39) = 1.4$, $p = 0.18$]. Corrected cued recall for attended words in the Name Word Color condition was also significantly different from zero [$t(39) = 4.0$, $p < .0001$], whereas that of ignored words did not differ significantly from zero [$t(39) = -0.0$, $p = 1$].

The overall effect of Study Task on corrected cued recall was determined with a one-way ANOVA for attended and ignored words separately. Analysis revealed that corrected cued recall was significantly higher in the Read Word condition compared to the Name Word Color condition for attended words [$F(1, 78) = 66.4$, $MSe = .006$, $p < .0001$]. There was no significant effect of Study Task on ignored words ($F < 2$).

*Priming-Corrected Cued Recall Correlation*

No correlation between priming and corrected cued recall was significant in any condition ($p > .05$).

## Discussion

The reading and naming ink colors of attended words in this experiment produced significant priming on the word stem completion test, although priming was significantly higher in the Read Word condition. Contrary to expectation, no significant priming was obtained for ignored words in the Read Word condition. There was, likewise, no significant priming of ignored words in the Name Word Color condition.

Corrected cued recall was significantly higher for attended words in the Read Word condition compared to the Name Word Color condition. There was no significant cued recall for ignored words in the Read Word or Name Word Color conditions.

Response accuracy in the Read Word condition was significantly lower than that in the Name Word Color condition. The significantly poorer task performance in the Read Word condition was due to errors in reading that led to the exclusion of several data points from the analysis. There were no significant differences between the RT in the two conditions, however, suggesting that there was no speed-accuracy tradeoff in the Read Word condition.

Priming for attended words in the Read Word condition was significantly higher than that for the Name Word Color condition. These results were consistent with those in the previous experiments. The presumed processing of attended words with shape analyzers did not produce significant priming of ignored words. In fact, there was a surprising significant negative priming of the ignored words in the Read Word condition. That priming for these words was significantly negative suggests that the interfering ignored words may have been inhibited. Active inhibition of ignored words could prevent reactivation and retrieval with word stem cues. This interpretation is similar to the explanation for other negative priming findings. When an ignored item on one trial becomes the relevant attended item on the following trial, the naming latency to the relevant item is delayed compared to that of a new item (Tipper, 1985). This condition of negative priming is attributed to the automatic activation in the type nodes of the item in a recognition network of familiar objects, words or symbols. The nodes of these ignored items are inhibited, together with any closely related nodes previously established through semantic or contextual links. It is this inhibition that makes it difficult to reactivate them later. Recent work by DeSchepper and Treisman (1996) shows that negative priming occurs even for novel shapes that have no preexisting representation, and that negative priming can occur for a long time, even up to a month. Experiment 3 suggests that negative priming of words may depend on active processing and subsequent inhibition of shape analyzers because negative priming was not obtained when using color analyzers for naming colors of words. The differences obtained were small, however, and this observation requires further study.

Priming of words following color naming in this experiment was significantly higher than that obtained in the same condition in the preceding experiments. It may be conjectured that the significantly higher priming in this experiment compared to that in the preceding experiments is directly related to the second word in the visual display during stimulus presentation. The presence of two words in the visual display probably made it more difficult for subjects to identify the target items. To overcome this difficulty the subjects probably processed the target words more than hitherto necessary before responding to the colors. This possible breakdown of filtering suggests that the subjects processed the shapes of the letters. The unintentional retrieval of memory of these letters in the word stem completion test probably accounted for the higher priming in the Name Word Color condition compared to levels obtained in the preceding experiments. Priming in the Name Word Color condition was, nevertheless, significantly lower compared to priming in the Read Word condition. The results again suggest that although word processing during color naming may be automatic, this process may not necessarily produce normal priming.

Explicit cued recall for words that were read was significantly higher than for those whose ink colors were named. These results are consistent with those in the preceding experiments. There was no cued recall for the unattended words in the Read Word and Name Word Color conditions. As already discussed, there is consensus from many studies that memory for unattended information is generally poor.

There was no significant correlation between priming and corrected cued recall in the Read Word and Name Word Color conditions for attended or ignored words. These outcomes imply that the subjects were not using the same strategies for the completion of implicit and explicit tests. The significantly higher priming compared to corrected cued recall in the Read Word and Name Word Color conditions for attended words also supports the conclusion that unconscious processes guided the completion of word stems in the implicit memory test (cf. Merikle & Reingold, 1991, 1992).

## Experiment 4

The recurring phenomenon in the preceding experiments was that despite some processing of words in the Name Word Color condition, priming was significantly lower compared to that derived from word reading. Priming was reduced whether the implicit test was word fragment completion or word stem completion. While this thesis was in preparation, however, new data from similar work by Szymanski and MacLeod (1996) were presented that suggested that priming following color naming was robust and normal when implicit memory was tested with a lexical decision task. It was, therefore, decided to examine the generalizability of these findings in this dissertation. The question addressed was whether the priming failures in the Name Word Color condition in the preceding experiments were due to the type of implicit memory tests used for reactivating memory of the processed words.

The transfer appropriate processing approach to memory emphasizes that repetition priming will benefit to the extent that processes engaged during the study of materials are reinstated at test. If the words are not processed for specific letter features during the color naming task, and the resultant records in the object files are only weak features like the colors or the shapes of the words, the presentation of degraded word fragments and word stems as cues may not be able to support a reactivation of the records. It is possible that the weak records may need stronger cues for their reactivation. The goal in Experiment 4 was to examine whether the presentation of cues of a different kind could be more beneficial for priming of words processed in the Name Word Color and possibly also in the Name XX Color conditions. If the word fragment and word stem tests used did not overlap the kind of word processing that occurred in the Name Word Color and Name XX Conditions, there was less probability for there to be implicit memory of these words.

The lexical decision task (LDT) presents a string of letters on a computer monitor to which subjects are required to quickly make yes/no decisions about whether the string constitutes an English word. Accuracy in this task is usually very high and so is not usually informative for making inferences about implicit memory for previously encountered words. The response speed is informative, however, because faster responses to previously encountered words compared to new words are assumed to reveal repetition priming (see for example, Forbach, Stanners, & Hochhaus, 1974; Scarborough, Cortese, & Scarborough, 1977; Scarborough, Gerard, & Cortese, 1979). The presentation of the whole word in this test may constitute a stronger record because it is more similar to what was presented before. The complete words could reactivate memory more easily for words presented in the stimulus presentation phase. It was expected that if the processing of words in the Name Word Color and Name XX Color conditions, and the resulting records created, overlapped those required for making yes/no decisions about strings of letters, repetition priming would be revealed for words presented during the study phase. Furthermore, if the aspects of word processing in the Name Word Color and Name XX Color conditions were similar to some aspects of word processing in the Read Word condition, the reenactment of these processes in the LDT would facilitate equal levels of repetition priming in all conditions. As before, explicit recognition of the words was expected to be poorer in the Name Word Color and Name XX Color conditions compared to the Read Word condition. Although some aspects of the words would be processed in the course of responding to colors of words or XXs, word processing was not expected to be as elaborate as that in the Read Word condition.

## Method

### *Subjects and Apparatus*

A new set of 60 undergraduates participated in the experiment for credit points. The criteria for participation were the same as those in the previous experiments. The apparatus was also the same.

### *Materials and Procedure*

The words studied were the same as those used in Experiments 2 or 3. Each subject was presented with a completely randomized version of one of the two lists of 60 words each. Stimulus presentation procedures were the same as those used in the previous experiments.

The 60 words in each of the lists were separated into two groups of 30 words each. The items in one group of 30 words were used for the assessment of implicit memory whereas the other group of 30 words assessed explicit memory. Two lists of 15 words each were further made from each group of 30 words.

For the implicit test (LDT), each subject was tested on either one of two sets of 30 words and 30 nonwords each. Each set comprised 15 of the words presented on the monitor, 15 matched nonpresented words, and 30 pronounceable nonwords. Thus, the baseline for words in List A was matched nonpresented words from List B. Likewise, the baseline for words in List B was the matched nonpresented words in List A. The pronounceable nonwords were made by rearranging the sequence of letters of the 30 words (presented and nonpresented) used in the implicit test. The rearrangement of letters was done to render the presented words meaningless while maintaining their main characterstics in terms of the letters, word length and word shape. This setup minimized the likelihood that the subjects made their word/nonword decisions on the basis of subtle cues like say word length. These subtle cues could have been present had nonwords differing markedly from those made from the presented words been introduced.

A similar procedure was used for explicit recognition of presented words. Each subject was tested on either of two sets of 30 words each. Each set contained 15 of the words presented on the monitor and 15 matched nonpresented words. No nonwords were presented in the task. Rather, the list of items comprised 30 words, half of which contained some of the presented words whereas the other half contained matched words from the nonpresented list.

*Lexical Decision Task (Implicit)*

Subjects were instructed to decide as quickly and accurately as possible whether a string of letters that appeared in the middle of the computer monitor constituted a word in the English language. They were specifically instructed that the essence of the test was to be as fast and accurate as possible.

Each subject completed 10 practice (LDT) trials before doing the actual test. At the start of the practice, subjects were instructed to rest their index fingers on the keys assigned to be pressed for the "yes" and "no" responses. For the "yes" responses, half of the subjects pushed the "z" key whereas the other half pushed the "/"or "?" key. The same rule was applied to the "no" responses. The sequence of stimulus presentation was as follows: Subjects pressed the space bar to start the test. Immediately after that, a fixation point appeared in the middle of the monitor for a 1 s duration. A string of letters was then presented in the middle of the monitor against a white background. All letters were in black uppercase in 24 point Helvetica font. The letters remained for a maximum of 3 s after which, if the subject had not responded, the next sequence of presentation was automatically initiated by the program. A trial in which a subject failed to make a response in the 3 s presentation time was counted as spoiled. The number of spoiled trials was rare and negligible. If a subject made a response within the 3 s duration, however, the next trial sequence began immediately. The words were completely randomized by the program before being presented to each subject. Subjects' response latencies and accuracies were recorded by the program.

*Explicit Recognition Task*

Subjects were asked to quickly decide whether any word presented in the middle of the computer monitor had been presented earlier during the study phase of the experiment. Again, the decision required pressing keys for "yes" and "no" answers. For each of the subjects, the keys used for the "yes" and "no" responses in the implicit test were maintained for responses in the explicit test. The program recorded response latencies and recognition accuracies.

## Results

*Study Task Performance*

There was no rejection of data because no subject admitted to using explicit retrieval strategies in the performance of the lexical decision task. The mean reaction times (RTs) and accuracies (% correct) in response to the presented words were each analyzed with a one way analysis of variance (ANOVA) with Study Task as the independent variable with three levels (Read Word vs. Name Word Color vs. Name XX Color). The summary of performance data is presented in Table 11. A total of 5 RT (0.13%) data points: Two in the Read Word and 3 in the Name Word color conditions was classified as outliers. There were no RT outliers in the Name XX Color condition.

Analysis of the RTs revealed a significant effect of Study Task [$F(2, 57) = 10.2$, $MSe = 10225.8$, $p < .0001$]. Posthoc analyses of this effect revealed that, as before, Name XX Color < Name Word Color = Read Word. The slower RTs for naming word colors compared to naming XX colors suggested that the words interfered with the color naming responses.

There was, therefore, a Stroop effect in ink colors naming. Analyses of performance accuracies revealed no significant differences between the groups ($F < 1$).

*LDT (Implicit Test)*

Mean RT and response accuracies (% correct) in the LDT were analyzed separately with a 3 (Study Task: Read Word vs. Name Word Color vs. Name XX Color) X 2 (Item Type: Presented word vs. Nonpresented word) mixed factorial ANOVA. See Tables 12 and 13 for a summary. The analyses on RT revealed no significant main effect of Study Task ($F < 1$), but a significant main effect of Item Type [$F(1, 57) = 37.9$, $MSe = 729.6$, $p < .0001$], and no significant Study Task X Item Type interaction ($F < 1$). Posthoc analysis of the effect of Item Type revealed that RT for Presented words < Nonpresented words. Analyses of response accuracies revealed no significant main effects or interactions (all $F$s < 1).

*Priming*

The subtraction of RTs for Nonpresented words from those of Presented words for the different Study Tasks gave the priming score. Separate analysis showed that priming was significantly different from zero in the Read Word [$t(19) = 2.7$, $p < .01$], Name Word Color [$t(19) = 3.3$, $p < .004$], and Name XX Color [$t(19) = 5.0$, $p < .0001$] conditions . A one-way ANOVA on the priming score failed to reveal a significant main effect of Study Task ($F < 1$).

*Explicit Recognition Test*

Mean RT and response accuracies (% Yes) in the explicit recognition test were analyzed separately with a 3 (Study Task: Read Word vs. Name Word Color vs. Name XX Color) X 2 (Item Type: Presented word vs. Nonpresented word) mixed factorial ANOVA. Again, see Table 12 for a summary. The analyses on RT revealed no significant main effect of Study Task ($F < 1$), but a significant main effect of Item Type [$F(1, 57) = 18.2$, $MSe = 18775.3$, $p < .0001$], and no significant Study Task X Item Type interaction ($F < 2$). Posthoc analysis of the effect of Item Type revealed that RT for Presented word < Nonpresented word.

Analyses of response accuracies (% Yes) revealed no significant main effect of Study Task ($F < 1$), a significant main effect of Item Type [$F(1, 57) = 30.3$, $MSe = 329.0$, $p < .0001$], and a significant Study Task X Item Type interaction [$F(2, 57) = 20.6$, $p < .0001$]. Further analysis of this interaction effect revealed that Hits > False Alarms for the Read Word condition only.

*Corrected Recognition*

The subtraction of % Yes responses for Nonpresented words from those of Presented words for the different Study Tasks gave the corrected recognition score. Separate analysis showed that corrected recognition in the Read Word [$t(19) = 5.7$, $p < .0001$] and Name Word Color [$t(19) = 2.4$, $p < .03$] conditions were significantly different from zero. Corrected recognition in the Name XX Color [$t(19) = -0.9$, $p = .38$] was not significantly different from zero.

A one-way ANOVA on corrected recognition revealed a significant main effect of Study Task [$F(2, 57) = 20.6$, $MSe = 658$, $p < .0001$]. Post hoc analyses of this effect revealed that corrected recognition in Read Word > Name Word Color = Name XX Color.

*Priming-Recognition Correlation*

There was no significant correlation between the scores in either the Read Word [$r(20) = .24$, $p = .3$] or Name Word Color [$r(20) = -.03$, $p = .88$] condition. The correlation was significant, however, in the Name XX Color [$r(20) = .43$, $p = .05$] condition.

## Discussion

Unlike the previous experiments, statistically significant and equal priming was obtained in all conditions: reading of target words and naming ink colors of words or XXs. In contrast, there was significantly better recognition of presented words in the Read Word Condition compared to similar measures in the Name Word Color and Name XX Color conditions. Word recognition in the Name XX Color condition was below the baseline. These results replicate exactly those reported by Szymanski and MacLeod (1996).

Similar to results in the preceding experiments, the typical Stroop interference effect was obtained. Because subjects responded to colors in the Name Word Color condition, the significant response delay compared to that in the Name XX color condition suggests that aspects of the words were automatically processed. In conformity with the performance data in

Experiments 1 and 2, word reading was unexpectedly slow compared to word color naming. The possible explanation for this outcome is again the relatively low frequency of the words used in the experiment coupled with filtering cost (see Discussion in Experiment 1).

That equal priming was obtained in all conditions suggests, therefore, that what was automatically processed in the Name Word Color condition was implicitly retrieved during the lexical decision task. Similar conclusions can be made about how subjects in the Name XX Color condition processed words during study and test.

It was predicted that if the processing of words in the Name Word Color and Name XX Color conditions overlapped those in the Read Word condition, and more important, for the lexical decision task, repetition priming would be equal in all conditions. The results of this experiment supported that hypothesis. This inference is circular, however, because it is based on the test outcome. Ideally, the processes that produced the robust priming should have been specified earlier to provide the basis for drawing the inference that overlapping processes at study and test produced the test outcome. It is at this stage not clear exactly what processes were engaged during study and how they were reenacted in the lexical decision task. Some plausible hypotheses about these processes will be considered, however, in the General Discussion.

The results also lend credibility to the view that priming of ignored words can occur after exposure to their physical characteristics, and that access to memory of that processing can later occur without intention (see Kellogg et al., 1993; Kinoshita, 1995; Szymanski & MacLeod, 1996). A reinstatement of the full words in the LDT likely presented a stronger stimulus that strongly reactivated processes that occurred at study and allowed repetition priming for the words. These automatically processed aspects of the words were not revealed with either the word fragment or word stem completion tests. The results of this experiment suggest, therefore, that the automaticity of repetition priming is dependent on the kind of implicit memory test used for reenacting processes engaged in study at test. They suggest that the automatic processes engaged during study were best reenacted in the lexical decision task. These results call for qualifications to the prevailing view that repetition priming is automatic and insensitive to attention manipulation at study.

Explicit recognition of presented words also confirmed the hypothesis that failure to attend to the words would result in poor explicit memory. Indeed, the results of this experiment produced a dissociation between implicit and explicit memory virtually identical to that reported by Szymanski and MacLeod (1966). Recognition of the presented words was poor when subjects did not directly attend and respond to these words during the study task. It is assumed that whatever processing of the words occurred during study in the Name Word Color and Name XX Color conditions was not sufficiently extensive to lay down strong memory traces for the words to be retrieved in a recognition test. By contrast, because all subjects in the Read Word condition responded to these words, it is assumed they processed the words in detail. The extensive processing in the Read Word condition laid down stronger memory traces that could be retrieved in a recognition test. Studies show poor explicit retention when critical information is not processed attentively at study (see for e.g., Eich, 1984; Parkin & Russo, 1990; Szymanski & MacLeod, 1996; Wippich, 1995).

The absence of significant correlation between priming and recognition in the Read Word and Name Word Color conditions implies that the subjects were not using the same strategies for the completion of implicit and explicit tests. The significant priming-corrected recognition correlation in the Name XX color condition suggests, however, that a common strategy may have been used in the completion of both tasks, although why this was only obtained in one condition is unclear. Subjects who named ink colors of XXs probably did not process the words beyond the features extracted. Because they had no strong memory traces to depend on for the recognition test, it is possible they relied on unconscious processes during test to complete even the nominally explicit recognition test. These unconscious processes are further implicated in this result because corrected recognition in the Name XX Color condition was less that the priming obtained. Such outcomes suggest unconscious processes (cf. Merikle & Reingold, 1991, 1992).

## General Discussion

A summary of the main findings from all four experiments follows:

1). In Experiment 1, the reading of target words produced significant priming in a word fragment completion task, similar to typical levels reported in many studies. Naming ink colors of the words or XXs produced marginal (and nonsignificant) priming, however. Thus, although there was indication of automatic processing of words in the Name Word Color condition, priming was minimal when attention to the target words was diverted with the color naming task. Explicit memory, as measured by cued recall, was also affected by the manipulation of attention to the target words. Although the expected dissociation between implicit and explicit memory was not obtained, the lack of positive correlation between priming and corrected cued recall supported the assumption that different retrieval strategies were used in the different memory tests.

2). In Experiment 2, the manipulation of attention again affected implicit and explicit memory performance. Repetition priming following word reading was significantly larger than priming following naming word or XX colors in a word stem completion test. Repetition priming following the color naming tasks was significant, however, although small. Cued recall was also significantly reduced in the color naming tasks. There was no significant correlation between priming and corrected cued recall in any of the conditions.

3) In Experiment 3, priming in a word stem completion test was again reduced by the name word color task. No priming was obtained for simultaneously presented but ignored words. Significant negative repetition

priming was obtained for ignored words when the study task involved reading, but not color naming of attended words. Cued recall was significantly higher for presented items in the Read Word condition compared to the Name Word Color condition. There was no significant cued recall for ignored words in the Read Word or Name Word Color conditions. Furthermore, there was no significant correlation between priming and corrected cued recall in any attended or ignored condition.
4). In Experiment 4, statistically significant and equivalent repetition priming was obtained in all study conditions (reading of target words, naming word or XX colors) using the LDT. In contrast, recognition was significantly better in the Read Word condition compared to the Name Word Color and Name XX Color conditions.

The overall interpretation of these results requires an understanding of the kinds of perceptual processes that the words may have engaged during the selection and response to different aspects of the visual displays. Second, it is important to understand the kinds of processes engaged during testing for memory of the words presented. The interpretation of these processes will be guided by the Feature Integration Theory of visual selective attention (Kahneman et al., 1983, 1992; Kahneman & Treisman, 1984; Treisman & Gelade, 1980) as outlined in Experiment 1, and the transfer appropriate processing approach to memory (e.g., Roediger, 1990b).

Perceptual Encoding Processes at Study

Task performance for the different conditions in this filtering paradigm may be conceived as beginning with the selection of the target (word or XXs) followed by the attribute of the object upon which the response was based. Treisman (1969) gives an example of such sequential processes in the selection and response to target items (see p. 284). There is the need to reiterate that stimuli were presented in a modified Stroop color-word, and a filtering paradigm. Three features of the filtering paradigm (Kahneman et al., 1983; Treisman et al., 1983) were present in the displays used. First, subjects in each condition were presented with simultaneous target and irrelevant items without foreknowledge of their respective locations. Second, the target stimuli controlled a relatively complex process of response selection and execution. Third, the property that distinguished the target from irrelevant stimuli was a simple physical feature that was different from the property that determined the appropriate response.

Subjects were required to respond with the ink color of the target item (word or XXs) or to read the target item (word). Selection was based on a box that surrounded the target item whereas the response was based on the condition (instruction). Thus the features of the letters controlled the pronunciations made to the words in the Read Word condition. Subjects in the Name Word color condition had to ignore the letters and make the appropriate color response. Likewise, in color naming XXs, responses were controlled by the specific colors and not the shapes of the letter.

In the Name XX Color condition, subjects selectively attended to events at locations that were opposite the locations for the words. Because these words were irrelevant for naming the XXs colors, they were probably only processed preattentively for their features and filtered out. Further intentional processing of the words would have hampered the goal of quickly naming the ink colors of the XXs. Percent accuracy in the XX color condition in these experiments suggests that the selection and response to the colors was performed at the same level as those in the other conditions. Subjects who named the ink colors of the words selected items displayed at the same location as those who read the words. The consistent Stroop interference effect in the Name Word Color conditions in Experiments 1, 2 and 4, suggests that some salient aspects of the words that had to be ignored were, nevertheless, processed. It is assumed that subjects in the reading condition processed the words fully, although there was the likely filtering cost of other irrelevant items in the display prior to word selection and processing (Kahneman et al., 1983; Treisman, et al., 1983). Probably, this is why reading was slower than expected.

Selective attention to the stimuli and the kind of information processing in the three conditions determined the kinds of object files created for the words. According to Feature Integration Theory, the processing of the words in the XX Color condition was at a feature level. Presumably, automatic preattentive processes categorized the visual display, identified the relevant object, and allocated more attention to the item until the appropriate response was executed. Object files would have been created for the words as well as the XX that were selected. The filtering of the irrelevant information in this condition means that probably only the rudimentary features of the words were categorized and retained as records in the respective object files. The words would have been processed for their salient features at the level of their physical characteristics, such as color, shape, size, or position before disappearing from the display.

In the Name Word Color condition, Feature Integration Theory would predict that interference in color naming occurred because when subjects selected the target item for color naming, they also selected all the irrelevant properties of the item (Kahneman & Henik, 1981; Kahneman & Treisman, 1984). The records of the object files would have contained all the salient features of the words such as shapes, colors, sizes, fonts, and even meanings. It is probable, however, that because the property that guided responses was the colors of the words, this property attained more prominence in the object files compared to the shapes of letters of the words. The perceptual records of the target items processed in the Read Word condition would have included the physical features including the shapes, size, etc. More important, however, word reading would have ensured that all the conceptual or semantic aspects were also stored as part of the records.

To sum up, it is speculated that the subjects in the Name XX condition processed words only at the feature level. Following the automatic and preattentive processing of the physical characteristics of the words, the records retained probably included the shapes and colors of the words. Irrelevant aspects of the words that interfered with the processing of ink colors in the Name Word Color condition probably included some of the salient physical characteristics of the words, like their shapes, colors, sizes, and orientations. It is possible that some semantic activation of these words would have occurred, although the results obtained in these experiments do not offer any indication that activation of word meanings during the color naming task influenced the performance of these subjects in either the implicit or explicit memory tests. As Kahneman, Treisman, and Gibbs (1992) suggest, attention to a property of the target relegates other less important properties to the background. It may be conjectured that because the colors of words guided responses in the color naming tasks, color features were prominent in the object files created. Processing of words in the Read Words condition likely included both their physical characteristics and conceptual or semantic interpretations.

## Transfer Appropriate Processing (TAP) and Retrieval Processes at Test

The key assumption of TAP is that performance on memory tests will benefit to the extent that operations required at test recapitulate or overlap the encoding operations performed during the learning episode. The modified version of this TAP approach (see Masson & Freedman, 1990; Masson & MacLeod, 1992) suggests that both data-driven and conceptually-driven processes operate to produce a context-dependent interpretation of a stimulus. Memory for an encoding episode is assumed to consist of the identifying and discriminative operations that were followed in developing an interpretation of the stimulus. This memory can be expressed when it is opportune to reenact the original encoding operation. The reapplication of procedures to identical or similar stimuli in the past is not always a conscious and individuated recollection of past episodes but can occur automatically through interaction with a stimulus and may be applied without awareness (Masson & Freedman, 1990). This memory for a prior episode can be engaged simply by exposure to the relevant stimuli and tasks. Remembering of the encoding episode is said to be most successful when the task conditions permit the entire collection of the encoding operation to be recruited (Masson, 1989; Masson & MacLeod, 1992). Studies show that priming is stronger when aspects of the encoding operations at study are reinstated at test (see Masson & Freedman, 1990; Masson & MacLeod, 1992; Smith, MacLeod, Bain, & Hoppe, 1989).

The implicit memory tests in Experiments 1, 2, and 3 presented degraded words as retrieval cues for the presented words. The results indicate that these cues were not beneficial for the implicit retrieval of the words processed in the Name Word Color or Name XX Color conditions. Priming in these conditions was significantly smaller compared to that in the Read Word condition. Although priming improved somewhat in Experiment 3, it was still significantly lower than that in the Read Word condition.

The poor priming for words in the Name XX color condition, and more so for the words in the Name Word Color condition, suggests that the operations instituted at test were unable to reenact the exact encoding operations of the words during study. In contrast, significant priming was obtained in these conditions when whole words were used as retrieval cues in the LDT. This facilitation in priming suggests that some aspects of the whole word cues facilitated a reenactment of word processing that occurred in all of the conditions. It may be speculated on the basis of the results from Experiment 4 that the shapes of the words or perhaps their abstract letter identities presented the critical cues that likely reactivated the perceptual encoding of words in the Name Word Color and Name XX Color conditions.

*Multilevel Model of Perceptual Analysis*

The multilevel model of perceptual analysis (Kirsner & Dunn, 1985) presents a similar idea to that of the transfer appropriate processing approach. Kirsner and Dunn suggest that repetition priming is achieved by reference to the perceptual record of information processed. Similarity between a stimulus and its record is the critical parameter for repetition priming. If the record collection includes an example that is similar to current stimulus description, identification is achieved easily and quickly even under difficult viewing conditions. If the record collection does not include an appropriate example, a more detailed description of the current stimulus will be required and performance will be impaired accordingly. Kirsner, Dunn, and Standen (1987) have advanced the argument that the character of the record collection can be determined by repetition priming. The magnitude of repetition priming depends on the extent to which the current stimulus description matches the record. They have suggested that it is the systematic manipulation of the relevant parameters that should reveal the precise character of the record. That priming of the words was as robust when subjects responded to the colors of words or XXs as it was when the words were read suggests that the perceptual records created for the words, regardless of the specific task performed during the study phase, included the word shapes. The nature of this record was revealed with cues that could reactivate these records.

*The Role of Word Shapes in Lexical Decision*

The idea that the shape of words could have been the critical aspects processed by subjects who did not directly respond to the words is not a new idea. According to Healy and Cunningham (1992) investigators like Cattell (1886), Erdmann and Dodge (1898) suggested in writings at the turn of the century that word shapes played a role in word recognition. Similar ideas have been presented by other researchers (e.g., Monk & Hulme, 1983). The role of word shape in word recognition is controversial, however. More influential theories do not allow for supraletter feature detection in word recognition (McClelland & Rumelhart, 1981). The suggestion that letter units play a central role in word recognition obviates the needs to postulate the independent contribution of word shapes in word identification (Besner, 1989; Oden, 1984; Paap, Newsome, & Noel, 1984).

The definition of word shape is itself controversial (Healy & Cunningham, 1992; Paap et al., 1984). For many researchers, the word shape is usually defined as the pattern of ascending and descending and neutral characters. When used in this way, the definition assumes that the word shape includes information about the length of the word and hence the number of letters and the smooth outline or envelope that surrounds the contours of the word. A second definition simply defines word shape as the surrounding outline. The latter definition suggests that shape feature might be ambiguous with respect to the precise number of letters in the words (Paap et al., 1984). Paap and his associates observe that most researchers define word shape in terms of the former. The results from some studies suggest that information about word shape is not limited to words in lowercase letters. Word shapes may be derived from words in uppercase letters too (Johnston & McClelland, 1974; Reicher, 1969).

In a now classic experiment, Reicher (1969) showed that words may first be processed as wholes before serial scanning to identify individual letters occurs. Reicher tested subjects on letter recognition performance. The subjects were presented with brief tachistoscopic displays of one to two single words, four-letter common words, or four-letter nonwords. The stimuli were immediately followed by a mask and two single letters. In a forced choice task, subjects had to choose which of the letters occupied a position marked by the spot on the mask where the letters were presented. For example, if the word presented was "WORK," the two letters displayed at the masked location previously occupied by the letter "K" would be "D" and "K." The correct and incorrect choices between the alternatives both spelled common words. Subjects were better at letter recognition when the presented and masked stimuli were words compared to single letters. According to the author, the results suggested that the first stages of information processing are done in parallel. It was further suggested that Gestalt field effects imply that whole figures are more easily seen than the elements of which they are made.

Reicher's findings have been replicated by others. Follow-up experiments using similar procedures hav found that letter detection was better when subjects attended to the whole word as compared with single letters (Carr, Davidson, & Hawkins, 1978; Johnston & McClelland, 1974; Wheeler, 1970). These results suggest that the shapes of words, even in upper case letters, may provide information that facilitates perception of the parts. The requirement for this to occur, however, is that the whole word must first be attended.

Other studies showing that word shapes may play a role in the perceptual encoding of words or identification of letters have been reported (see Johnston & McClelland, 1973; McClelland & Johnston, 1977). Neisser (1967) has suggested that early passive analyzers operate in parallel on information after which further construction of the percept operates serially. The construction processes presumably can enable a word to be constructed instead of the separate letters that compose the word. Neisser's ideas have also been echoed by Carr, Polatsek, and Posner (1981). Carr and his associates have presented the view that the system of word encoding is composed of several relatively independent stimulus analyzing mechanisms that operate largely in parallel with each of these mechanisms presenting an output that is a code representing some attribute of the stimulus. These codes could be those representing the visual configuration, pronunciation, or semantic content. They argue that which codes are attended and what relations between codes are computed depends on the task requirement.

*Word Processing Reenactment and Repetition Priming*

The ideas suggested in these theoretical and empirical writings is that it is possible to process aspects of a word without emphasizing the elements that make up the word. The brief presentation of words in the Name Word Color and Name XX Color possibly precluded detailed analysis of the letters in those words because the subjects had been prompted to process colors and ignore words. It has been suggested that some features of these words were nevertheless extracted. The theoretical explanation behind this assumption has already been outlined. It is assumed that the features extracted were the shapes of the words and fewer of the letter elements. Because word processing was probably at the level of whole words, the retrieval operation of these processes at test could not be successful in word fragment and word stem completion tests. The word fragment completion and word stem completion test may have called for a different reconstructive bottom-up operation that differed from that during the study phase. The results obtained in Experiment 4, as well as those of Szymanski and MacLeod (1996) strongly suggest that the LDT facilitated a reenactment of the operations that were used in the processing of the words.

Alternatively, the features of the words extracted during stimulus presentation could have been their abstract letter identities. Abstract letter identities (ALI) are defined as non-visual, nonphonological, case independent, font-independent, abstract representations of words (see Bigsby, 1990). According to some models of word recognition (e.g., Coltheart, 1981) initial feature analysis of words is followed by the assignment of ALIs to each of the letters. These ALIs may then be passed either letter by letter (i.e., serially) or 'en bloc' (i.e., in parallel) to an orthographic lexicon. Indeed, other researchers have proposed the idea that visual codes may be generated for words that do not receive focal attention (McConkie & Zola, 1979; Rayner, McConkie, & Ehrlich, 1978). McConkie and Zola have suggested that the processing of parafoveal words may provide a code that represents characteristics of the words more abstract than the purely visual characteristic but short of a semantic identification. This intermediary code that might represent letters, orthographic patterns, phonemic or articulatory codes, or a combination of these presumably facilitates the naming of words. If these codes or ALIs were generated at study in all groups and reenacted during the lexical decision task, they may explain the significant repetition priming obtained in Experiment 4.

Scarborough et al. (1979) reported repetition priming after subjects had pronounced words at their first encounter, although subjects did not benefit from prior exposure in the performance of a recognition test. There was thus a dissociation between repetition priming and recognition tests in their study. Scarborough and his associates could not specify the exact mechanism that accounted for the repetition effect. Indeed, they could not attribute the effect to simple feature or letter detectors because repetition effects persisted even when the stimulus was changed between initial presentation and testing in terms of letter orientation, or in terms of upper vs. lower case letters as reported by Scarborough et al. (1977). Scarborough et al. (1979) hypothesized that the level of coding affected by repetition involves very complex representations of the stimuli, perhaps in terms of letter clusters or even the whole word. They further suggested that the repetition effect produced after the pronunciation of a word may occur only if the word is later presented in a similar or systematically related form. A reinstatement of memories of the words processed in Experiment 4 through the LDT produced the robust priming for all conditions that was not possible with the word fragment or word stem completion tests.

The repeated presentation of a word is presumed to recruit episodic memories of recent experiences with that word. Evidence of this contextual specificity as revealed in the LDT supports the view that the repetition effect is based on episodic memory for processes that construct a conceptual interpretation of the target. These episodic memories can be recruited in parallel and automatically as a result of interaction with a stimulus that can be applied to current processing without awareness (Masson & Freedman, 1990).

The results of Experiment 4 support those reported by Szymanski and MacLeod (1996), who found no significant difference between prior word reading and color naming on a subsequent lexical decision task. Recognition performance in their study was, however, reliably higher following the word reading compared to ink color naming task. The lexical decision task was presumably able to reenact the processes that were involved in processing the words at study. The results of this experiment also support the failure of attention manipulation to affect performance on a lexical decision task (Kinoshita, 1995). The lexical decision task showed a significant effect of prior exposure to words whether they were attended or unattended, apparently because the processes engaged during study of the information were reenacted in the LDT.

*Attention, Automatic Information Processing, and Implicit Memory*

This study has shown that manipulation of attention with the Stroop color-word paradigm significantly reduced repetition priming for unattended words and did not produce dissociations between implicit and explicit memory when these memory measures were tested with word fragment and word stems tests. These results suggest that attention to the words during stimulus presentation was necessary for there to be normal priming. Normal performance on implicit and explicit memory tests using word fragment and word stems test may therefore depend on the allocation of attention to information during study.

The foregoing discussion also suggests that subjects automatically processed some aspects of the words to which they were not required to respond. Preattentive and automatic categorization of information in the visual display is suggested in the selective attention paradigm used. Subjects who selectively processed the colors of XXs, nevertheless, likely also processed some aspects of the words presented in distant locations from the XXs. The automatic processing of words whose colors were named was evident in the Stroop interference reported in Experiments 1, 2, and 4. Because word processing proceeded automatically despite the task performed in the different conditions, it was expected that repetition priming for the words would be revealed in the word fragment and word stem completion tests. The consistent failure to obtain priming at the level obtained for word reading in Experiments 1, 2, and 3 was the clearest demonstration that the presumed automaticity of implicit memory following automatic processing of unattended information has to be qualified. It may not be useful to assume that implicit memory will be revealed automatically on any implicit memory test. Automaticity in priming, as the results of this study show, depends on the implicit memory test used. Priming will not be automatic if the test is unable to reenact the exact automatic processing of the information presented during study.

*Retrieval Operations for Explicit Memory*

Explicit cued recall in all the experiments was poorer when subjects responded to the colors of words or XXs compared to reading of the words. Experiment 4 demonstrated a dissociation between implicit and explicit memory, confirming that of Szymanski and MacLeod (1996). There was robust repetition priming in the LDT after subjects had attended and responded to the colors of words or the colors of XXs. Explicit recognition of words following these task processes was, however, significantly poorer compared to similar measures for those who read the words. These results conform to those reported in many of the studies reviewed in the introduction. The results are also in conformity with the prediction made about memory performance in the transfer appropriate processing theory. Memory performance is facilitated by the extent to which the operation required at test recapitulate or overlap the encoding operations performed during study. The results support the suggestion that the words were probably processed at the feature level. Features processed in the color naming conditions, as the LDT results indicate, were likely the shapes or the abstract letter identity of the words. This rudimentary processing of words did not facilitate the laying down of strong memory traces. The features extracted could not be processed elaborately to promote the formation of associations between the learned items and existing concepts in memory (MacLeod & Bassili, 1989). Because relational information could not result from the preattentive processing of the words in the Name Word Color and Name XX Color conditions, the necessary relational information assumed to result from encoding operations could not be formed. The associative pathway resulting from processing features of the words resulted in a sparse network that could not support explicit retrieval of the words as demanded in the cued recall and recognition tests. As MacLeod and Bassili have argued, richer relational networks provide more entry points as well as more alternative routes for reaching items in memory than do sparse networks. The results from these experiments suggest that word reading facilitated the formation of a richer relational network that could support explicit retrieval of information. In contrast, word color naming or naming XXs did not facilitate the rich relational network necessary to support explicit retrieval of the words.

Except for Experiment 4, the pattern of results of the implicit memory tests was generally similar to that of the explicit memory tests. This similarity of results may suggest that subjects used intentional or conscious recollection strategies for the completion of implicit and explicit memory tests in these experiments. Although it may be difficult to ensure a complete elimination of conscious retrieval strategies in the completion of the implicit memory tests, a number of procedures were introduced to limit the influence of conscious recollection strategies.

First, contamination of conscious retrieval strategies was reduced through using the retrieval intentionality criterion in the construction of implicit and explicit memory tests. Second, implicit memory of the words was consistently tested first followed by explicit memory. Third, subjects were thoroughly interviewed to determine whether they had used explicit retrieval strategies for the completion of implicit memory test. Data from subjects who used conscious recollection strategies in the completion of implicit memory test were consistently removed from the data base and were not included in any of the analyses reported in this study. Finally, correlations were performed on the implicit and explicit memory test data to assess the possible contamination of strategies in test performance. The rationale for these procedures have already been outlined (see General Method). Although these procedures by no means ensured the complete elimination of conscious recollection strategies in the implicit and explicit memory test performance in these experiments, their collective use strongly suggest that the patterns of results obtained was likely not due to contamination of strategies.

## Summary and Conclusion

This dissertation has considered the role of attention in dissociations between implicit and explicit memory. The review of the literature in the introduction showed an emerging consensus that dissociations following the manipulation of attention during study have almost exclusively been attributed to automatic processing of information. It was pointed out that post hoc explanations of these dissociative effects were not justified since some studies have shown that presumed unattended information can, nevertheless, be processed attentively. It was suggested that a better strategy was to provide objective indicators of automatic information processing during the manipulation of attention at study. These indicators would then provide the basis upon which the prevailing assumptions could be tested.

Implicit and explicit memory for words presented in a modified Stroop color-word and a filtering paradigm were assessed with word fragment completion, word stem completion, and lexical decision tasks. The results showed that focal attention to the words was crucial for normal priming when implicit memory was tested with word fragment completion and word stem completion tests but not lexical decision task. One may conjecture that different processes may underlie word fragment completion, word stem completion, and lexical decision task, although they are all classified as perceptual implicit memory tests (cf. Moscovitch et al., 1994). The results of this study suggest that whereas performance in word fragment completion or word stem completion tests may require analysis at the letter level, lexical decision tasks may require analysis at the word level.

The results were interpreted within the framework of feature integration theory and the transfer appropriate processing approach to memory. A reenactment of word processing operations during study in the lexical decision task was found to be crucial for robust priming when critical stimuli were presumably unattended. The proposition that word shapes likely accounted for the significant priming revealed for all conditions (word reading, word color or XX color naming) in the lexical decision task is plausible, though largely untested. Future investigations may test this assumption and perhaps reveal a better way in which the results obtained so far can be better explained. Until that time arrives, however, it is reasonable to assume that word shapes may very well be one of the features extracted early in the processing of words presented.

This dissertation concludes that focal attention to the words presented was important for normal performance in both implicit and explicit memory tests using the word fragment completion or word stem completion tests. Some automatic processing of words occurred during stimulus presentation. This process was, however, inadequate in facilitating normal priming on implicit memory tests that could not reenact encoding operations at test. Automatic processes also did not benefit explicit retrieval of information. The assumed insensitivity of implicit memory to the manipulation of attention during study therefore needs to be closely reexamined to determine the extent to which the assumptions apply and the limitations.

Table 1

Studies Manipulating Attention Between Modalities (Divided Attention)

| Study | Attention Manipulation and Study Task | Modality[a] | Memory Measure Implicit | Memory Measure Explicit | Implicit F (Attention)[b] | Explicit F (Attention) |
|---|---|---|---|---|---|---|
| Parkin & Russo (1990) | Picture completion + tone monitoring | V[c] + A[d] | Picture completion | Free recall | NO | YES |
| Schmitter-Edgecombe (1996) | Word rating + tone monitoring | V + A | Category association; Perceptual clarification; Tachistoscopic identification | Graphemic cued recall Semantic cued recall | NO | YES |

table continues

| Study | Attention Manipulation and Study Task | Modality[a] | Memory Measure Implicit | Memory Measure Explicit | Implicit F (Attention)[b] | Explicit F (Attention) |
|---|---|---|---|---|---|---|
| Parkin, Reid, & Russo (1990) | Sentence verification + tone monitoring | V + A | Fragment completion | Recognition | NO | YES |
| Isingrini, Vazou, & Leroy (1993) | Word rating + target detection | V + A | Category exemplar generation | Cued recall | NO | YES |
| Gardiner & Parkin (1990) | Word learning + tone monitoring | V + A | Know | Remember | NO | YES |
| Jacoby et al. (1989) | Name reading + target detection | V + A | Fame judgment | Recognition | NO | YES |

table continues

| Study | Attention Manipulation and Study Task | Modality[a] | Memory Measure | | Implicit F (Attention)[b] | Explicit F (Attention) |
|---|---|---|---|---|---|---|
| | | | Implicit | Explicit | | |
| Koriat & Feuerstein (1976) | Word learning + digit symbol task | A + V | Free association | Free recall<br>Recognition | NO | YES |

[a] V = Visual, A = Auditory

[b] F(Attention) designates "a function of attention."

c Material to be tested

d Distractor task

Table 2

Studies Manipulating Attention Within Modality (Dichotic Listening)

| Study | Attention Manipulation and Study Task | Modality[a] | Memory Measure | | Implicit | Explicit |
|---|---|---|---|---|---|---|
| | | | Implicit | Explicit | F (Attention)[b] | F (Attention) |
| Eich (1984) | Shadowing prose + homophone pairs | A | Homophone spelling | Recognition | NO | YES |
| Wilson (1979) | Shadowing prose + tones | A | Tone preference | Recognition | NO | YES |

table continues

| Study | Attention Manipulation and Study Task | Modality[a] | Memory Measure Implicit | Memory Measure Explicit | Implicit F (Attention)[b] | Explicit F (Attention) |
|---|---|---|---|---|---|---|
| Anooshian (1989) | Shadowing prose + homophone pairs | A | Homophone spelling/ Free association to words | Recognition | YES | YES |

[a] A = Auditory
[b] F(Attention) designates "a function of attention."

Table 3

Studies Manipulating Attention Within Modality (Filtering)

| Study | Attention Manipulation and Study Task | Modality[a] | Memory Measure | | Implicit F (Attention)[b] | Explicit F (Attention) |
|---|---|---|---|---|---|---|
| | | | Implicit | Explicit | | |
| Merikle & Reingold (1984) | Selective word processing | V | Contrast sensitivity | Recognition | NO | YES |
| Wolters & Phaf (1990) | Selective word processing | V | Word stem completion; Threshold identification | Free recall | NO | YES |
| Kinoshita (1995) | Word or digit processing | V | Lexical decision | Recognition | NO | YES |

table continues

| Study | Attention Manipulation and Study Task | Modality[a] | Memory Measure | | Implicit F (Attention)[b] | Explicit F (Attention) |
|---|---|---|---|---|---|---|
| | | | Implicit | Explicit | | |
| Kellogg et al. (1993) | Word or digit processing | V | Lexical decision | Recognition | NO | YES |
| Grand & Segal (1966) | Stroop paradigm | V | Word association | Free recall | NO | YES |
| Wippich (1995) | Stroop paradigm | V | Word stem completion | Word stem completion | NO | YES |

table continues

| Study | Attention Manipulation and Study Task | Modality[a] | Memory Measure | | Implicit F (Attention)[b] | Explicit F (Attention) |
|---|---|---|---|---|---|---|
| | | | Implicit | Explicit | | |
| Szymanski & MacLeod (1996) | Stroop paradigm | V | Lexical decision | Recognition | NO | YES |

[a] V = Visual
[b] F(Attention) designates "a function of attention."

Table 4

Studies Manipulating Attention With Brief Visual Presentation of Stimuli

| Study | Attention Manipulation and Study Task | Modality[a] | Memory Measure: Implicit | Memory Measure: Explicit | Implicit F (Attention)[b] | Explicit F (Attention) |
|---|---|---|---|---|---|---|
| Seamon et al. (1983) | Brief exposure + shadowing prose | V + A | Preference of stimuli | Recognition | NO | YES |
| Hawley & Johnston (1991) | Brief exposure + flanking | V | Perceptual memory | Recognition | YES | YES |

[a] A = Auditory
[b] F(Attention) designates "a function of attention."

Table 5

Mean Reaction Times (RTs) and Response Accuracies for Experiment 1.

| Study Task | RT (ms) | Accuracy (% correct) |
|---|---|---|
| Read Word | 768 (21.0) | 89 (1.3) |
| Name Word Color | 732 (8.3) | 89 (1.6) |
| Name XX Color | 649 (15.0) | 88 (1.6) |

Note: The standard errors are shown in parentheses.

Table 6

Word Fragment Completion in Experiment 1

| | Implicit Memory Test | | | Explicit Memory Test | | |
|---|---|---|---|---|---|---|
| Study Task | Presented (Target) | Nonpresented (Baseline) | Priming | Presented (Hits) | Nonpresented (False Alarms) | Corrected Cued Recall |
| Read Word | .36 | .14 | .22 | .36 | .24 | .12 |
| Name Word Color | .20 | .15 | .05 | .18 | .24 | -.06 |
| Name XX Color | .15 | .10 | .05 | .14 | .15 | -.01 |

Table 7

Mean Reaction Times (RTs) and Response Accuracies for Experiment 2.

| Study Task | RT (ms) | Accuracy (% correct) |
|---|---|---|
| Read Word | 784<br>(18.1) | 92<br>(.95) |
| Name Word Color | 756<br>(13.7) | 92<br>(.96) |
| Name XX Color | 622<br>(10.6) | 93<br>(.85) |

Note: The standard errors are shown in parentheses.

Table 8

Word Stem Completion in Experiment 2

| | Implicit Memory Test | | | Explicit Memory Test | | |
|---|---|---|---|---|---|---|
| Study Task | Presented (Target) | Nonpresented (Baseline) | Priming | Presented (Hits) | Nonpresented (False Alarms) | Corrected Cued Recall |
| Read Word | .24 | .04 | .20 | .21 | .04 | .17 |
| Name Word Color | .09 | .03 | .06 | .06 | .02 | .04 |
| Name XX Color | .06 | .02 | .04 | .05 | .02 | .03 |

Table 9

Mean Reaction Times (RTs) and Response Accuracies for Experiment 3.

| Study Task | RT (ms) | Accuracy (% correct) |
|---|---|---|
| Read Word | 704<br>(18.2) | 81<br>(1.7) |
| Name Word Color | 765<br>(18.7) | 93<br>(1.05) |

Note: The standard errors are shown in parentheses.

Table 10A

Word Stem Completion for Attended Words in Experiment 3

| | Implicit Memory Test | | | Explicit Memory Test | | |
|---|---|---|---|---|---|---|
| Study Task | Presented (Target) | Nonpresented (Baseline) | Priming | Presented (Hits) | Nonpresented (False Alarms) | Corrected Cued Recall |
| Read Word | .26 | .03 | .23 | .17 | .00 | .17 |
| Name Word Color | .17 | .02 | .15 | .03 | .00 | .03 |

Table 10B

Word Stem Completion for Ignored Words in Experiment 3

| | Implicit Memory Test | | | Explicit Memory Test | | |
|---|---|---|---|---|---|---|
| Study Task | Presented (Target) | Nonpresented (Baseline) | Priming | Presented (Hits) | Nonpresented (False Alarms) | Corrected Cued Recall |
| Read Word | .02 | .05 | -.03 | .01 | .00 | .01 |
| Name Word Color | .04 | .06 | -.02 | .00 | .00 | .00 |

Table 11

Mean Reaction Times (RTs) and Response Accuracies for Experiment 4.

| Study Task | RT (ms) | Accuracy (% correct) |
|---|---|---|
| Read Word | 788 (22.1) | 93 (0.7) |
| Name Word Color | 759 (25.1) | 95 (1.1) |
| Name XX Color | 651 (20.2) | 96 (1.2) |

Note: The standard errors are shown in parentheses.

Table 12

Reaction Time and Recognition Rates in Experiment 4

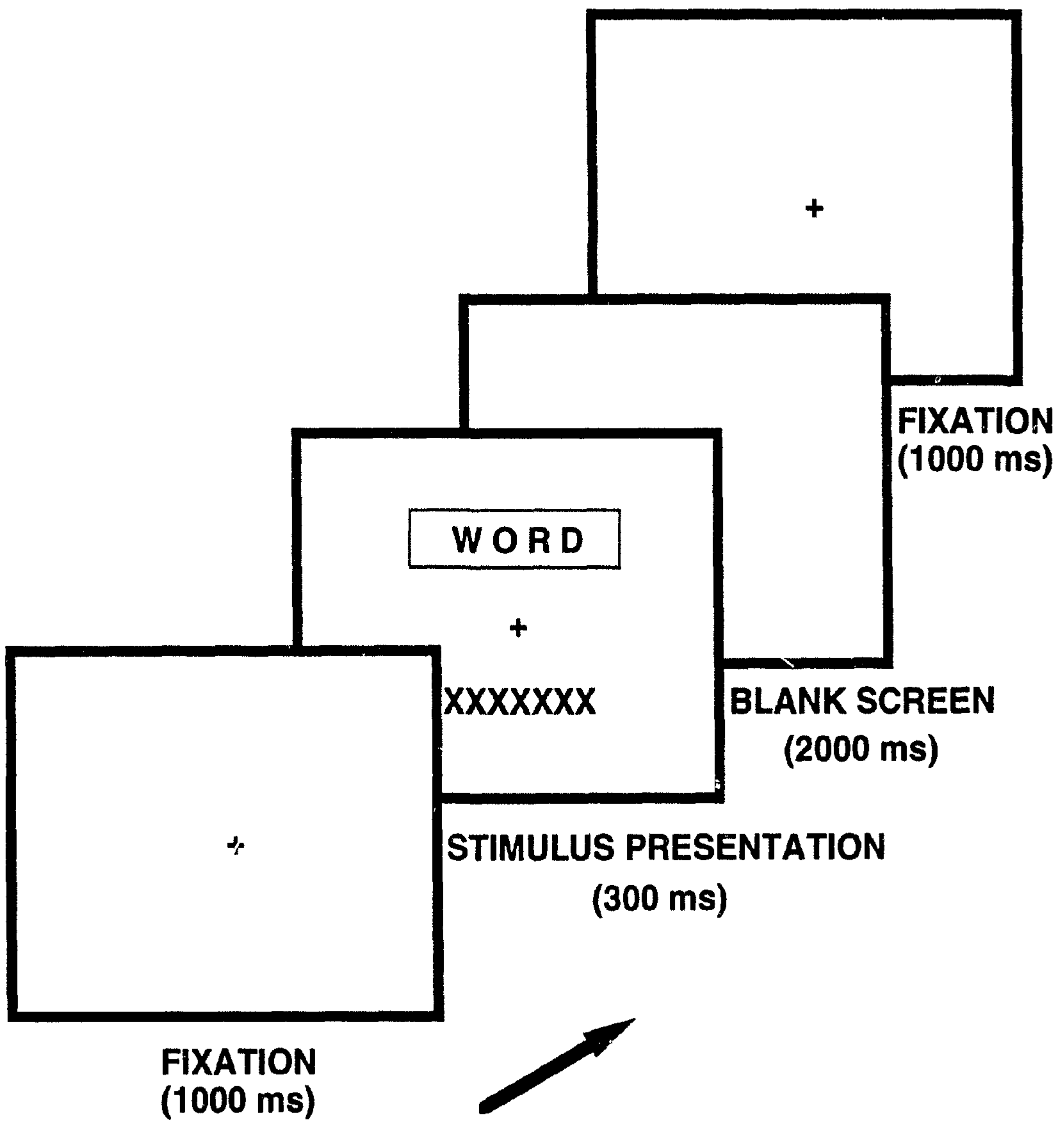
| Study Task | Implicit Memory Test RT (ms) | | | Explicit Memory Test Recognition (% Yes) | | |
|---|---|---|---|---|---|---|
| | Presented (Target) | Nonpresented (Baseline) | Priming | Presented (Hits) | Nonpresented (False Alarms) | Corrected Recognition |
| Read Word | 545 | 573 | 28 | .70 | .22 | .48 |
| Name Word Color | 567 | 595 | 28 | .50 | .39 | .11 |
| Name XX Color | 560 | 596 | 36 | .47 | .50 | -.03 |

Table 13

Performance in Lexical Decision Task in Experiment 4

| | Accuracy (% Correct) | |
|---|---|---|
| Study Task | Presented | Nonpresented |
| Read Word | 94 | 92 |
| Name Word Color | 95 | 93 |
| Name XX Color | 93 | 95 |

*Figure 1.* Schematic Presentation of a Trial



Appendix A

List A Words and Fragments

| Word | Frequency | Letters | Syllables | Fragments |
|---|---|---|---|---|
| DRIVEWAY | 3 | 8 | 2 | D _ I _ _ W A _ |
| CALCIUM | 9 | 7 | 2 | C _ _ C I _ M |
| LEMONADE | 7 | 8 | 3 | _ _ M O _ A _ E |
| GINGHAM | 5 | 7 | 2 | _ _ N G _ A M |
| SHERBET | 2 | 7 | 2 | _ H _ R B _ _ |
| CUSTARD | 5 | 7 | 2 | C U _ _ A _ D |
| DIAMETER | 17 | 8 | 4 | D _ _ M _ _ E R |
| SPARROW | 22 | 7 | 2 | _ P A _ _ O _ |
| ELASTIC | 12 | 7 | 3 | E _ _ S T _ _ |
| POSTCARD | 1 | 8 | 2 | _ O _ T C _ R D |
| LAUNDRY | 9 | 7 | 2 | L _ U N _ R _ |
| REINDEER | 6 | 8 | 2 | _ E I _ D E _ R |
| SPINACH | 8 | 7 | 2 | _ P I _ _ C _ |
| DOLPHIN | 4 | 7 | 2 | _ _ L P _ _ N |
| SAILBOAT | 2 | 8 | 2 | S _ I L _ _ A _ |
| NEWSREEL | 1 | 8 | 2 | N _ _ S R _ E _ |
| TRIANGLE | 8 | 8 | 3 | _ R I _ N _ _ E |
| VINEYARD | 8 | 8 | 2 | V _ _ E Y _ R _ |
| OCCUPANT | 7 | 8 | 3 | _ C _ U P _ N T |
| ICEBERG | 4 | 7 | 2 | I _ E B _ _ _ |
| DENTIST | 9 | 7 | 2 | _ E N _ _ S _ |

| Word | Frequency | Letters | Syllables | Fragments |
|---|---|---|---|---|
| MACARONI | 2 | 8 | 4 | _ A C _ R _ N _ |
| OVERFLOW | 15 | 8 | 3 | O _ E _ F _ O _ |
| UTENSIL | 8 | 7 | 3 | U _ E N _ I _ |
| CEREMONY | 25 | 8 | 4 | _ _ R E _ _ N Y |
| KEYBOARD | 1 | 8 | 2 | K _ _ B _ A R _ |
| OILCLOTH | 3 | 8 | 2 | _ _ L C L _ _ H |
| VELOCITY | 8 | 8 | 4 | V _ _ O C _ T _ |
| OBSERVER | 26 | 8 | 3 | O _ S _ _ V _ R |
| MERCURY | 21 | 7 | 3 | _ E R C _ R _ |
| LOTTERY | 4 | 7 | 3 | L _ _ T _ _ Y |
| CORRIDOR | 15 | 8 | 3 | C _ R _ _ D O _ |
| AMATEUR | 14 | 7 | 3 | A M _ _ E U _ |
| GOLDFISH | 1 | 8 | 2 | _ O _ D F _ _ H |
| BALLOON | 17 | 7 | 2 | _ A L _ _ O _ |
| VERANDA | 8 | 7 | 3 | V E _ _ N _ _ |
| RIGHTFUL | 5 | 8 | 2 | R _ _ H _ F _ L |
| FORMULA | 11 | 7 | 3 | F O _ _ U L _ |
| SCORPION | 3 | 8 | 2 | _ C _ R P _ O _ |
| EVENTFUL | 2 | 8 | 3 | E _ E _ T F _ _ |
| ANYWHERE | 34 | 8 | 3 | A _ _ W _ _ R E |
| CALENDAR | 10 | 8 | 3 | _ A _ E N _ A _ |
| RADIATOR | 6 | 8 | 3 | R _ D I _ _ O _ |
| SEASIDE | 4 | 7 | 2 | _ E A _ _ D _ |
| VANILLA | 5 | 7 | 3 | _ _ N I _ _ A |

| Word | Frequency | Letters | Syllables | Fragments |
|---|---|---|---|---|
| SIDEWALK | 18 | 8 | 2 | _ _ D E W _ _ K |
| SYLLABLE | 11 | 8 | 3 | _ Y _ L A _ L E |
| DELIVERY | 14 | 8 | 4 | D E _ _ V _ _ Y |
| EIGHTEEN | 44 | 8 | 2 | E I _ _ _ E E _ |
| FIREMAN | 9 | 7 | 2 | _ I R _ _ A N |
| TWILIGHT | 29 | 8 | 2 | T _ I _ I _ H _ |
| TADPOLE | 2 | 7 | 2 | _ A D _ _ L _ |
| NEEDLESS | 11 | 8 | 2 | N _ E _ L _ _ S |
| GALLERY | 28 | 7 | 3 | _ _ L _ E _ Y |
| EYESIGHT | 3 | 8 | 2 | E _ E S _ _ H _ |
| DEPOSIT | 41 | 7 | 3 | _ E _ O S _ T |
| TAXPAYER | 5 | 8 | 3 | T _ _ P A _ E _ |
| WHISKER | 6 | 7 | 2 | _ H _ S K _ R |
| PAYROLL | 1 | 7 | 2 | _ A _ R O _ L |
| FURNACE | 29 | 7 | 2 | _ U _ N _ C _ |
| Sum | 648 | 453 | 152 | |
| **Mean** | **10.8** | **7.5** | **2.5** | |
| SD | 10.0 | 0.5 | 0.6 | |
| SEM | 1.3 | 0.1 | 0.1 | |

Note: Word frequencies are based on the Thorndike-Lorge (1944) count. These words were presented during the stimulus presentation phase of Experiment 1.

List B Words and Fragments

| Word | Frequency | Letters | Syllables | Fragments |
|---|---|---|---|---|
| REVIEWER | 1 | 8 | 3 | R _ _ I _ W _ R |
| AILMENT | 5 | 7 | 2 | _ I L _ _ N T |
| COTTAGE | 46 | 7 | 2 | C _ _ T A _ E |
| APPROVAL | 14 | 8 | 3 | A _ _ R _ V A _ |
| SILKWORM | 2 | 8 | 2 | S _ L _ _ O R _ |
| BRACELET | 10 | 8 | 2 | _ R _ C E _ E _ |
| SHIPMENT | 9 | 8 | 2 | _ _ I P _ E _ T |
| FARMYARD | 4 | 8 | 2 | _ A _ M _ _ R D |
| KNAPSACK | 2 | 8 | 2 | K _ A _ _ A C _ |
| HILLTOP | 5 | 7 | 2 | _ I _ L T _ _ |
| EMERALD | 9 | 7 | 3 | _ M _ R _ _ D |
| AUCTION | 5 | 7 | 2 | A _ C _ I _ N |
| LAVENDER | 11 | 8 | 3 | L _ _ E N _ E _ |
| ACADEMY | 17 | 7 | 4 | _ C A _ _ M _ |
| TRICYCLE | 1 | 8 | 3 | T _ I _ Y _ L _ |
| SIXPENCE | 6 | 8 | 2 | S _ _ P E _ C _ |
| APOLOGY | 8 | 7 | 4 | _ P O _ O G _ |
| LOOPHOLE | 4 | 8 | 2 | L _ O _ H _ L _ |
| GERANIUM | 4 | 8 | 3 | _ _ R A _ I U _ |
| PORTRAIT | 19 | 8 | 2 | _ O _ T R _ I T |
| BATTERY | 19 | 7 | 3 | B A _ T _ _ Y |

| Word | Frequency | Letters | Syllables | Fragments |
|---|---|---|---|---|
| SUNLIGHT | 32 | 8 | 2 | _U__IG_T |
| STADIUM | 2 | 7 | 2 | _T_DI__ |
| MIXTURE | 39 | 7 | 2 | M_X___E |
| PAINTING | 45 | 8 | 2 | __IN_IN_ |
| CHARCOAL | 11 | 8 | 2 | _H_RC_AL |
| SERGEANT | 18 | 8 | 2 | S__GE_NT |
| RHUBARB | 3 | 7 | 2 | _HU_A_B |
| RAINDROP | 5 | 8 | 2 | R_I__R_P |
| NIGHTCAP | 2 | 8 | 2 | _I_HT_A_ |
| FRECKLE | 8 | 7 | 2 | FR__K_E |
| LANDLORD | 12 | 8 | 2 | _A_DL__D |
| BEDROOM | 35 | 7 | 2 | _ED__O_ |
| DWELLING | 26 | 8 | 2 | DW__L_N_ |
| VAGABOND | 8 | 8 | 3 | V__AB__D |
| CANNIBAL | 4 | 8 | 3 | C_NN__AL |
| BRIGADE | 8 | 7 | 2 | _RI__DE |
| AIRCRAFT | 2 | 8 | 2 | A__C_AF_ |
| EDITION | 19 | 7 | 3 | _DI__O_ |
| STARFISH | 3 | 8 | 2 | _T_RF__H |
| TWEEZERS | 1 | 8 | 2 | T_E_Z_R_ |
| DAFFODIL | 3 | 8 | 3 | _AF__DI_ |
| ORTHODOX | 5 | 8 | 3 | O_T_O__X |
| CONFETTI | 1 | 8 | 3 | C__FE__I |
| MOSQUITO | 8 | 8 | 3 | M_S__I_O |

| Word | Frequency | Letters | Syllables | Fragments |
|---|---|---|---|---|
| BONFIRE | 3 | 7 | 3 | B _ _ F _ R E |
| DIAGRAM | 7 | 7 | 3 | D _ _ G _ _ M |
| BOULDER | 5 | 7 | 2 | B O _ _ D E _ |
| CHAIRMAN | 22 | 8 | 2 | C _ A I _ _ A N |
| BUNGALOW | 8 | 8 | 3 | B _ _ G A _ O _ |
| LINOLEUM | 4 | 8 | 3 | _ I _ O L E _ M |
| ARMCHAIR | 6 | 8 | 2 | A _ M C _ _ I _ |
| MISCHIEF | 20 | 8 | 2 | M _ _ _ H _ _ F |
| TOWNSHIP | 9 | 8 | 2 | T _ W _ S _ _ P |
| MANSION | 18 | 7 | 2 | M _ N S I _ _ |
| PANCAKE | 6 | 7 | 2 | P _ N C _ _ _ |
| PLACARD | 3 | 7 | 2 | P L _ _ _ R D |
| RINGLET | 2 | 7 | 2 | R _ N G _ _ _ |
| KILOGRAM | 1 | 8 | 3 | K _ _ O G R _ _ |
| MOONBEAM | 2 | 8 | 2 | M _ _ N B _ A _ |
| Sum | 617 | 458 | 143 | |
| **Mean** | **10.2** | **7.6** | **2.3** | |
| SD | 10.8 | 0.4 | 0.5 | |
| SEM | 1.3 | 0.1 | 0.1 | |

Note: Word frequencies are based on the Thorndike-Lorge (1944) count. These words and fragments were not presented during the stimulus presentation phase of Experiment 1.

Appendix B

List A Words and Word Stems.

| Word | Frequency | Letters | Syllables | Stems |
|---|---|---|---|---|
| MARBLE | 38 | 6 | 2 | MAR________ |
| CORPSE | 9 | 6 | 1 | COR________ |
| PLANK | 19 | 5 | 1 | PLA________ |
| NURSERY | 19 | 7 | 3 | NUR________ |
| GENERATOR | 2 | 9 | 4 | GEN________ |
| GLACIER | 28 | 7 | 2 | GLA________ |
| ABOLITION | 7 | 9 | 4 | ABO________ |
| CANDY | 32 | 5 | 2 | CAN________ |
| LOCKER | 3 | 6 | 2 | LOC________ |
| HOUND | 23 | 5 | 1 | HOU________ |
| MACARONI | 2 | 8 | 4 | MAC________ |
| AFFECTION | 37 | 9 | 3 | AFF________ |
| SALOON | 12 | 6 | 2 | SAL________ |
| CELLAR | 32 | 6 | 2 | CEL________ |
| SPRAY | 22 | 5 | 1 | SPR________ |
| SLUSH | 1 | 5 | 1 | SLU________ |
| SCARLET | 27 | 7 | 2 | SCA________ |
| MANTLE | 19 | 6 | 2 | MAN________ |
| BRONZE | 19 | 6 | 1 | BRO________ |
| BRIGADE | 8 | 7 | 2 | BRI________ |
| FLOTILLA | 1 | 8 | 3 | FLO________ |

| Word | Frequency | Letters | Syllables | Stems |
|---|---|---|---|---|
| DISCIPLE | 6 | 8 | 3 | DIS__________ |
| FRACTION | 12 | 8 | 2 | FRA__________ |
| GARLIC | 3 | 6 | 2 | GAR__________ |
| ACROBAT | 1 | 7 | 3 | ACR__________ |
| HURDLE | 2 | 6 | 2 | HUR__________ |
| STAGECOACH | 3 | 10 | 2 | STA__________ |
| BULLET | 22 | 6 | 2 | BUL__________ |
| MONARCH | 20 | 7 | 2 | MON__________ |
| ACCORDION | 1 | 9 | 3 | ACC__________ |
| GRAPE | 34 | 5 | 1 | GRA__________ |
| GROOVE | 8 | 6 | 1 | GRO__________ |
| SINGER | 20 | 6 | 2 | SIN__________ |
| HARMONY | 23 | 7 | 3 | HAR__________ |
| BLACKSMITH | 19 | 10 | 2 | BLA__________ |
| ADMIRAL | 20 | 7 | 3 | ADM__________ |
| PRAIRIE | 25 | 7 | 2 | PRA__________ |
| MUSICIAN | 18 | 8 | 3 | MUS__________ |
| BEAVER | 23 | 6 | 2 | BEA__________ |
| LEATHER | 50 | 7 | 2 | LEA__________ |
| AVALANCHE | 4 | 9 | 3 | AVA__________ |
| TABLESPOON | 24 | 10 | 3 | TAB__________ |
| BOSOM | 27 | 5 | 2 | BOS__________ |
| TROUPE | 1 | 6 | 1 | TRO__________ |
| THORN | 24 | 5 | 1 | THO__________ |

| Word | Frequency | Letters | Syllables | Stems |
|---|---|---|---|---|
| SCORPION | 3 | 8 | 3 | SCO________ |
| SLIPPER | 20 | 7 | 2 | SLI________ |
| CLASSROOM | 3 | 9 | 2 | CLA________ |
| JUGGLER | 1 | 7 | 2 | JUG________ |
| CREDENCE | 1 | 8 | 2 | CRE________ |
| PARACHUTE | 5 | 9 | 3 | PAR________ |
| RELATION | 50 | 8 | 3 | REL________ |
| REVOLVER | 9 | 8 | 3 | REV________ |
| SKULL | 13 | 5 | 1 | SKU________ |
| BARREL | 32 | 6 | 2 | BAR________ |
| MISSILE | 2 | 7 | 2 | MIS________ |
| IMPULSE | 26 | 7 | 2 | IMP________ |
| HAMMER | 34 | 6 | 2 | HAM________ |
| AMBULANCE | 8 | 9 | 3 | AMB________ |
| POSTER | 5 | 6 | 2 | POS________ |
| Sum | 962 | 419 | 131 | |
| **Mean** | **16.0** | **6.9** | **2.1** | |
| SD | 12.8 | 1.4 | 0.7 | |
| SEM | 1.6 | 0.2 | 0.1 | |

Note: Word frequencies are based on the Thorndike-Lorge (1944) count.

List B Words and Word Stems.

| Word | Frequency | Letters | Syllables | Stem |
|---|---|---|---|---|
| CHARCOAL | 11 | 8 | 2 | CHA_________ |
| MORGUE | 2 | 6 | 1 | MOR_________ |
| BUTCHER | 22 | 7 | 2 | BUT_________ |
| TRUMPET | 17 | 7 | 2 | TRU_________ |
| SULPHUR | 21 | 7 | 2 | SUL_________ |
| REPTILE | 8 | 7 | 2 | REP_________ |
| TWEEZERS | 1 | 8 | 2 | TWE_________ |
| STEAMER | 28 | 7 | 2 | STE_________ |
| PROTOPLASM | 5 | 10 | 4 | PRO_________ |
| DEFENDER | 7 | 8 | 3 | DEF_________ |
| SPINACH | 8 | 7 | 2 | SPI_________ |
| DEPOSIT | 41 | 7 | 3 | DEP_________ |
| DRAINAGE | 9 | 8 | 2 | DRA_________ |
| SKILLET | 2 | 7 | 2 | SKI_________ |
| BOUQUET | 8 | 7 | 2 | BOU_________ |
| EXPEDITION | 40 | 10 | 4 | EXP_________ |
| REFRIGERATOR | 11 | 12 | 5 | REF_________ |
| GALAXY | 3 | 6 | 3 | GAL_________ |
| ARROW | 37 | 5 | 2 | ARR_________ |
| FILAMENT | 7 | 8 | 3 | FIL_________ |
| FIREPLACE | 19 | 9 | 2 | FIR_________ |
| TOAST | 20 | 5 | 1 | TOA_________ |

| Word | Frequency | Letters | Syllables | Stem |
|---|---|---|---|---|
| POLICEMAN | 22 | 9 | 3 | POL__________ |
| DAMSEL | 36 | 6 | 2 | DAM__________ |
| HILLSIDE | 20 | 8 | 2 | HIL__________ |
| RESONANCE | 1 | 9 | 3 | RES__________ |
| SHEEPSKIN | 2 | 9 | 2 | SHE__________ |
| TOBACCO | 36 | 7 | 3 | TOB__________ |
| WIGWAM | 1 | 6 | 2 | WIG__________ |
| RETINUE | 3 | 7 | 3 | RET__________ |
| FLASK | 4 | 5 | 1 | FLA__________ |
| CONSCRIPT | 1 | 9 | 2 | CON__________ |
| BUNGALOW | 8 | 8 | 3 | BUN__________ |
| TIMEPIECE | 1 | 9 | 2 | TIM__________ |
| NOOSE | 2 | 5 | 1 | NOO__________ |
| BASEMENT | 8 | 8 | 2 | BAS__________ |
| ICEBOX | 1 | 6 | 2 | ICE__________ |
| MICROSCOPE | 3 | 10 | 3 | MIC__________ |
| BURIAL | 14 | 6 | 2 | BUR__________ |
| TENTACLE | 3 | 8 | 3 | TEN__________ |
| THIRTEEN | 34 | 8 | 2 | THI__________ |
| THRONE | 43 | 6 | 1 | THR__________ |
| TRACTOR | 12 | 7 | 2 | TRA__________ |
| HEADLIGHT | 2 | 9 | 2 | HEA__________ |
| BAGPIPE | 1 | 7 | 2 | BAG__________ |
| HONEYCOMB | 2 | 9 | 3 | HON__________ |

| Word | Frequency | Letters | Syllables | Stem |
|---|---|---|---|---|
| PEACH | 29 | 5 | 1 | PEA_________ |
| LANDSCAPE | 19 | 9 | 2 | LAN_________ |
| TRIUMPH | 41 | 7 | 2 | TRI_________ |
| SWAMP | 29 | 5 | 1 | SWA_________ |
| PRIEST | 42 | 6 | 1 | PRI_________ |
| HAIRPIN | 1 | 7 | 2 | HAI_________ |
| NIGHTFALL | 5 | 9 | 2 | NIG_________ |
| FISHERMAN | 26 | 9 | 3 | FIS_________ |
| SHOTGUN | 3 | 7 | 2 | SHO_________ |
| FOOTWEAR | 1 | 8 | 2 | FOO_________ |
| SUNBURN | 3 | 7 | 2 | SUN_________ |
| BANQUET | 18 | 7 | 2 | BAN_________ |
| WEAPON | 42 | 6 | 2 | WEA_________ |
| FOREHEAD | 41 | 8 | 2 | FOR_________ |
| Sum | 887 | 447 | 132 | |
| **Mean** | **14.7** | **7.4** | **2.2** | |
| SD | 14.2 | 1.4 | 0.7 | |
| SEM | 1.8 | 0.2 | 0.1 | |

Note: Word frequencies are based on the Thorndike-Lorge (1944) count.

## References

Allport, A. D., Antonis, B., & Reynolds, P. (1972). On the division of attention: A disproof of the single channel hypothesis. *Quarterly Journal of Experimental Psychology, 24,* 225-235.

Anooshian, L. J. (1989). Effects of attentive encoding on analytic and nonanalytic processing in implicit and explicit retrieval tasks. *Bulletin of the Psychonomic Society, 27*, 5-8.

Besner, D. (1989). On the role of outline shape and word specific visual pattern in the identification of function words: None. *Quarterly Journal of Experimental Psychology, 41A,* 91-105.

Bigsby, P. (1990). Abstract letter identities and developmental dyslexia. *British Journal of Psychology, 81*, 227-263.

Blaxton, T. A. (1989). Investigating dissociations among memory measures: Support for a transfer appropriate processing framework. *Journal of Experimental Psychology: Learning, Memory and Cognition, 15*, 657-668.

Briand, K. A. (1993). Efficient filtering of irrelevant global and local information when target level and location are random. *Psychological Research, 55,* 264-269.

Briand, K. A. (1994). Selective attention to global and local structure of objects: Alternative measures of nontarget processing. *Perception & Psychophysics, 55,* 562-574.

Carr, T. H., Davidson, B. J., & Hawkins, H. L. (1978). Perceptual flexibility in word recognition: Strategies affect orthographic computation but not lexical access. *Journal of Experimental Psychology: Human Perception and Performance, 4,* 674-690.

Carr, T. H., Pollatsek, A., & Posner, M. I. (1981). What does the visual system know about words? *Perception & Psychophysics, 29,* 183-190.

Cattell, J. M. (1886). The time taken up by cerebral operations. *Mind, 11*, 220-242, 377-392, 524-538.

Challis, B. H., & Brodbeck, D. R. (1992). Levels of processing affects priming in word fragment completion. *Journal of Experimental Psychology: Learning, Memory and Cognition, 18,* 5[illegible]5-607.

Cohen, J. D., Dunbar, K., & McClelland, J. L. (1990). On the control of automatic processes: A parallel distributed processing account of the Stroop effect. *Psychological Review, 97,* 332-361.

Cohen, L. S., & Squire L. R. (1980). Preserved learning and retention of pattern-analyzing skill in amnesia: Dissociation of "knowing how" and "knowing that." *Science, 210*, 207-210.

Coltheart, M. (1981). Disorders of reading and their implications for models of reading. *Visible Language, 15,* 245-286.

Craik, F. I. M., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of Experimental Psychology: General, 104,* 268-294.

Dalrymple-Alford, E. C., & Azkoul, J. (1972). The locus of interference in the Stroop and related tasks. *Perception and Psychophysics, 11,* 385-388.

DeSchepper, B., & Treisman, A. (1996). Visual memory for novel shapes: Implicit coding without attention. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 27-47.

Dunn, K. C., & Kirsner, K. (1989). Implicit memory: Task or process? In S. Lewandowsky, J. C. Dunn, & K. Kirsner (Eds.), *Implicit memory: Theoretical issues* (pp. 17-31). Hillsdale, NJ: Erlbaum.

Dyer, F. N. (1973). The Stroop phenomenon and its use in the study of perceptual, cognitive and response processes. *Memory & Cognition, 1,* 106-120.

Eich, E. (1984). Memory for unattended events: Remembering with and without awareness. *Memory & Cognition, 12*, 105-111.

Erdmann, B., & Dodge, R. (1898). Psychologische untersuchungen über das lesen, auf experimetaller grundlage [Psychological investigation of reading, on an experimental basis]. Halle, Germany: Niemeyer.

Eskes, G. A., Bryson, S. E., & McCormick, T. A. (1990). Comprehension of concrete and abstract words in autistic children. *Journal of Autism and Developmental Disorders, 20,* 61-73.

Fraisse, P. (1969). Why is color-naming longer than reading? *Acta Psychologica, 30,* 96-103.

Forbach, G. R., Stanners, R. F., Hochhaus, L. (1974). Repetition and practice effect in a lexical decision task. *Memory & Cognition, 2,* 337-339.

Francolini, C. M., & Egeth, H. E. (1980). On the nonautomaticity of "automatic" activation: Evidence of selective seeing. *Perception & Psychophysics, 27,* 331-342.

Gardiner, J. M., & Parkin, A. J. (1990). Attention and recollective experience in recognition memory. *Memory & Cognition, 18,* 579-583.

Ghoneim, M. M., Block, R. I., Sum Ping, S. T., Ali, M. A., & Hoffman, J. G. (1990). Learning without recall during general anesthesia. In B. Bonke, W. Fitch, & K. Millar (Eds.), *Memory and awareness in anesthesia* (pp. 161-169). Amsterdam: Swets & Zeitlinger.

Graf, P. (1994). Explicit and implicit memory: A decade of research. In C. Umiltà & M. Moscovitch (Eds.), *Attention and Performance XV* (pp. 681-696). Cambridge, MA: MIT Press.

Graf, P., & Mandler, G. (1984). Activation makes words more accessible, but not necessarily more retrievable. *Journal of Verbal Learning and Verbal Behavior, 23,* 553-568.

Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11,* 501-518.

Graf, P., Shimamura, A. P., & Squire, L. R. (1985). Priming across modalities and priming across category levels: Extending the domain of preserved function in amnesia. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11,* 385-392.

Graf, P., Squire, L. R., & Mandler, G. (1984). The information that amnesic patients do not forget. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10,* 164-178.

Grand, S., & Segal, S. J. (1966). Recovery in the absence of recall: An investigation of color-word interference. *Journal of Experimental Psychology, 72,* 138-144.

Green, R. L. (1996). The influence of experimental design: The example of the Brown Peterson paradigm. *Canadian Journal of Experimental Psychology, 50,* 240-242.

Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General, 108,* 356-388.

Hawley, K. J., & Johnston, W. A. (1991). Long term perceptual memory for briefly exposed words as a function of awareness and attention. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 17,* 807-815.

Hayman, G. A. C., & Tulving, E. (1989). Contingent dissociation between recognition and fragment completion: The method of triangulation. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 15,* 228-240.

Healy, A. F., & Cunningham, T. F. (1992). A developmental evaluation of the role of word shape in word recognition. *Memory & Cognition, 20,* 141-150.

Isingrini, M., Vazou, F., & Leroy, P. (1995). Dissociation of implicit and explicit memory tests: Effect of age and divided attention on category exemplar generation and cued recall. *Memory & Cognition, 23,* 462-467.

Jacoby, L. L. (1983). Remembering the data: Analyzing interactive processes in reading. *Journal of Verbal Learning and Verbal Behavior, 22*, 485-508.

Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General, 110*, 306-340.

Jacoby, L. L., Woloshyn, V., & Kelley, C. M. (1989). Becoming famous without being recognized: Unconscious influences of memory produced by dividing attention. *Journal of Experimental Psychology: General, 118,* 115-125.

Johnston, J. C., & McClelland, J. L. (1973). Visual factors in word perception. *Perception & Psychophysics, 14*, 365-370.

Johnston, J. C., & McClelland, J. L. (1974). Perception of letters in words: Seek not and ye shall find. *Science, 184,* 1192-1193.

Johnson, M. K., & Hasher, L. (1987). Human learning and memory. *Annual Review of Psychology, 38,* 631-668.

Kahneman, D., & Henik, A. (1981). Perceptual organization and attention. In M. Kubovy & J. R. Pomerantz (Eds.), *Perceptual organization* (pp. 181-211). Hillsdale, NJ: Erlbaum.

Kahneman, D., & Treisman, A. (1984). Changing views of attention and automaticity. In R. Parasuraman & D. R. Davis (Eds.), *Varieties of attention* (pp. 29-61). New York: Academic Press.

Kahneman, D., Treisman, A., & Burkell, J. (1983). The cost of visual filtering. *Journal of Experimental Psychology: Human Perception, and Performance, 9,* 510-522.

Kahneman, D., Treisman, A., & Gibbs, B. J. (1992). The reviewing of object files: Object-specific integration of information. *Cognitive Psychology, 24*, 175-219.

Kellogg, R. T., Newcombe, C., Kammer, D., & Schmitt, K. (1993, November). *Attention in explicit and implicit memory tasks with short and long term probes*. Paper presented at the annual meeting of the Psychonomic Society, Washington, D. C.

Kihlstrom, J. F., Schacter, D. L., Cork, R. C., Hurt, C. A., & Behr, S. E. (1990). Implicit and explicit memory following surgical anesthesia. *Psychological Science, 1*, 303-306.

Kinoshita, S. (1995). The word frequency effect in recognition memory versus repetition priming. *Memory & Cognition, 23*, 569-580.

Kirsner, K., & Dunn, J. C. (1985). The perceptual record: A common factor in repetition priming and attribute retention? In M. I. Posner & O. S. M. Marin (Eds.), *Attention and Performance XI* (pp. 547-565). Hillsdale, NJ: Erlbaum.

Kirsner, K., Milech, D., & Standen, P. (1983). Common and modality-specific processes in the mental lexicon. *Memory & Cognition, 11*, 621-630.

Kirsner, K., Dunn, J., & Standen. P. (1987). Record-based word recognition. In M. Coltheart (Ed.), *Attention and Performance XII* (pp. 147-167). Hillsdale, NJ: Erlbaum.

Klein, G. S. (1964). Semantic power measured through the interference of words with color naming. *American Journal of Psychology, 77*, 576-588.

Komatsu, S. I., & Ohta, N. (1984). Priming effects in word fragment completion for short and long retention intervals. *Japanese Psychological Review, 26,* 194-200.

Koriat, A., & Feuerstein, N. (1976). The recovery of incidentally acquired information. *Acta Psychologica, 40,* 463-474.

Kunst-Wilson, W. R., & Zajonc, R. B. (1980). Affective discrimination of stimuli that cannot be recognized. *Science, 207,* 557-558.

Light, L. L., & La Voie, D. (1993). Direct and indirect measures of memory in old age. In P. Graf & M. E. J. Masson (Eds.), *Implicit memory: New directions in cognition, development and neuropsychology* (pp. 207-230). Hillsdale, NJ: Erlbaum.

Logan, G. D. (1988). Toward an instance theory of automatization. *Psychological Review, 95,* 492-527.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109,* 163-203.

MacLeod, C. M. (1992). The Stroop task: The "gold standard" of attentional measures. *Journal of Experimental Psychology: General, 121,* 12-14.

MacLeod, C. M., & Bassili, J. N. (1989). Are implicit and explicit tests differentially sensitive to item-specific versus relational information? In S. Lewandowsky, J. C. Dunn, & K. Kirsner (Eds.), *Implicit memory: Theoretical issues* (pp. 159-172). Hillsdale, NJ: Erlbaum.

MacLeod, C. M., & Dunbar, K. (1988). Training and Stroop-like interference: Evidence for a continuum of automaticity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14,* 126-135.

Mandler, G., Nakamura, Y., & Van Zandt, B. J. S. (1987). Nonspecific effects of exposure on stimuli that cannot be recognized. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 646-648.

Masson, M. E. J. (1989). Fluent reprocessing as an implicit expression of experience. In S. Lewandowsky, J. C. Dunn, & K. Kirsner (Eds.), *Implicit memory: Theoretical issues* (pp. 123-138). Hillsdale, NJ: Erlbaum.

Masson, M. E. J., & Freedman, L. (1990). Fluent identification of repeated words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 355-373.

Masson, M. E. J., & MacLeod, C. M. (1992). Reenacting the route to interpretation: Enhanced perceptual identification without prior perception. *Journal of Experimental Psychology: General, 121,* 145-176.

McClelland, J. L., & Johnston, J. C. (1977). The role of familiar units in perception of words and nonwords. *Perception & Psychophysics, 22,* 249-261.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effect in letter perception: Part I. An account of basic findings. *Psychological Review, 88,* 375-407.

McConkie, G. W., & Zola, D. (1979). Is visual information integrated across successive fixations in reading? *Perception & Psychophysics, 25,* 221-224.

Merikle, P. M., & Reingold, E. M. (1991). Comparing direct (explicit) and indirect (implicit) measures to study unconscious memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 224-233.

Merikle, P. M., & Reingold, E. M. (1992). Measuring unconscious perceptual processes. In R. F. Bornstein & T. S. Pittman (Eds.), *Perception without awareness: Cognitive, clinical, and social perspectives* (pp. 55-80). New York: Guilford Press.

Mishkin, M. T., Malamut, B., & Bachevalier, J. (1984). Memory and habits: Two neural systems. In J. L. McGaugh, G. Lynch, & N. M. Weinberger (Eds.), *Neurobiology of learning and memory* (pp. 69-77). New York: Guilford Press.

Monk, A. F., & Hulme, C. (1983). Errors in proof reading: Evidence for the use of word shape in word recognition. *Memory & Cognition, 11*, 16-23.

Moscovitch, M., Goshen-Gottstein, Y., & Vriezen, E. (1994). Memory without conscious recollection: A tutorial review from a neuropsychological perspective. In C. Umiltà & M. Moscovitch (Eds.), *Attention and Performance XV* (pp. 619-660). Cambridge, MA: MIT Press.

Neisser, U. (1967). *Cognitive psychology.* New York: Appleton-Century-Crofts.

Oden, G. C. (1984). Dependence, independence, and emergence of word features. *Journal of Experimental Psychology: Human Perception, and Performance, 10,* 394-405.

Paap, K. R., Newsome, S. L., & Noel, R. W. (1984). Word shape's in poor shape for the race to the lexicon. *Journal of Experimental Psychology: Human Perception, and Performance, 10,* 413-428.

Paquet, L., & Merikle, P. M. (1988). Global precedence in attended and nonattended objects. *Journal of Experimental Psychology: Human Perception, and Performance, 14,* 89-100.

Parkin, A. J. (1989). The development and nature of implicit memory. In S. Lewandowsky, J. C. Dunn, & K. Kirsner (Eds.), *Implicit memory: Theoretical issues* (pp. 231-240). Hillsdale, NJ: Erlbaum.

Parkin, A, J., & Russo, R. (1990). Implicit and explicit memory and the automatic-effortful distinction. *European Journal of Cognitive Psychology, 2,* 71-80.

Parkin, A. J., Reid, T. K., & Russo, R. (1990). On the differential nature of implicit and explicit memory. *Memory & Cognition, 18,* 507-514.

Polster, M. R., Gray, P. A., McCarthy, R. A., & Park, G. R. (1990). Implicit and explicit memory after intra-muscular midazolam. In B. Bonke, W. Fitch, & K. Millar (Eds.), *Memory and awareness in anesthesia* (pp. 272-280). Amsterdam: Swets & Zeitlinger.

Posner, M. I., & Snyder, C. R. R. (1975). Attention and cognitive control. In R. L. Solso (Ed.), *Information processing and cognition: The Loyola symposium* (pp. 55-85). Hillsdale, NJ: Erlbaum.

Rajaram, S., & Roediger, H. L. (1993). Direct comparison of four implicit memory tests. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 765-776.

Rayner, K., McConkie, G. W., & Ehrlich, S. (1978). Eye movements and integrating information across fixations. *Journal of Experimental Psychology: Human Perception and Performance, 4,* 529-544.

Regan, J. (1978). Involuntary automatic processing in color-naming tasks. *Perception & Psychophysics, 24,* 130-136.

Reicher, G. M. (1969). Perceptual recognition as a function of meaningfulness of stimulus material. *Jcurnal of Experimental Psychology, 81,* 275-280.

Richardson-Klavehn, A., & Bjork, R. A. (1988). Measures of memory. *Annual Review of Psychology, 39,* 475-543.

Roediger, H. L. (1990a). Implicit memory: A commentary. *Bulletin of the Psychonomic Society, 28,* 373-380.

Roediger, H. L. (1990b). Implicit memory: Retention without remembering. *American Psychologist, 45,* 1043-1056.

Roediger, H. L., & Blaxton, T. A. (1987). Effects of varying modality, surface features and retention interval on priming in word fragment completion. *Memory & Cognition, 15,* 379-388.

Roediger, H. L., & Srinivas, K. (1993). Specificity of operations in perceptual priming. In P. Graf & M. E. J. Masson (Eds.), *Implicit memory: New directions in cognition, development and neuropsychology* (pp. 17-48). Hillsdale, NJ: Erlbaum.

Roediger, H. L., Weldon, M. S., & Challis, B. H. (1989). Explaining dissociations between implicit and explicit measures of retention: A processing account. In H. L. Roediger & F. I. M. Craik (Eds.), *Varieties of memory and consciousness. Essays in honour of Endel Tulving* (pp. 3-41). Hillsdale, NJ: Erlbaum.

Roediger, H. L., Weldon, M. S., Stadler, M. L., & Riegler, G. L. (1992). Direct comparison of two implicit memory tests: Word fragment and word stem completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18*, 1251-1269.

Roediger, H. L., & Weldon, M. S. (1987). Reversing the picture superiority effect. In M. A. McDaniel & M. Pressley (Eds.), *Imagery and related mnemonic processes: Theories, individual differences, and applications* (pp. 151-174). New York: Springer Verlag.

Scarborough, D. L., Cortese, C., & Scarborough, H. S. (1977). Frequency and repetition effects in lexical memory. *Journal of Experimental Psychology: Human Perception and Performance, 3,* 1-17.

Scarborough, D. L., Gerard, L., & Cortese, C. (1979). Accessing lexical memory: The transfer of word repetition effects across task and modality. *Memory & Cognition, 7,* 3-12.

Schacter, D. L. (1985). Priming of old and new knowledge in amnesic patients and normal subjects. *Annals of the New York Academy of Sciences, 444,* 41-53.

Schacter, D. L. (1987). Implicit memory: History and current status. *Journal of Experimental Psychology, Learning, Memory, and Cognition, 13*, 501-518.

Schacter, D. L. (1990). Introduction to "implicit memory: multiple perspectives." *Bulletin of the Psychonomic Society, 28,* 338-340.

Schacter, D. L., & Graf, P. (1986). Effects of elaborative processing on implicit and explicit memory for new associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12*, 432-444.

Schacter, D. L., Bowers, J., & Booker, J. (1989). Intention, awareness, and implicit memory: The retrieval intentionality criterion. In S. Lewandowsky, J. C. Dunn, & K. Kirsner (Eds.), *Implicit memory: Theoretical issues* (pp. 47-65). Hillsdale, NJ: Erlbaum.

Schmitter-Edgecombe, M. (1996). The effects of divided attention on implicit and explicit memory performance. *Journal of International Neuropsychological Society, 2,* 111-125.

Seamon, J. G., Brody, N., & Kauff, D. M. (1983). Affective discrimination of stimuli that are not recognized: Effects of shadowing, masking, and cerebral laterality. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 9,* 544-555.

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing II. Perceptual learning, automatic attending, and a general theory. *Psychological Review, 84,* 127-190.

Sloman, S. A., Hayman, C. A. G., Ohta, N., Law, J., & Tulving, E. (1988). Forgetting in primed fragment completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*, 223-239.

Smith, M. C., MacLeod, C. M., Bain, J. D., & Hoppe, R. B. (1989). Lexical decision as an indirect test of memory: Repetition priming and list-wide priming as a function of type of encoding. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 1109-1118.

Srinivas, K., & Roediger, H. L. (1990). Testing the nature of two implicit tests: Dissociation between conceptually-driven and data-driven processes. *Journal of Memory and Language, 29,* 389-412.

Stadler, M. A. (1995). The role of attention in implicit learning. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 21,* 674-685.

Strayer, D. L., & Kramer, A. K. (1990). An analysis of memory based theories of automaticity. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 16,* 291-304.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18,* 643-662.

Szymanski, K. F., & MacLeod, C. M. (1996). Manipulation of attention at study affects an explicit but not an implicit test of memory. *Consciousness & Cognition, 5,* 165-175.

Thorndike, E. L., & Lorge, I. (1944). *The teacher's wordbook of 30,000 words.* New York: Teachers' College, Bureau of Publications.

Tipper, S. P. (1985). The negative priming effect: Inhibitory priming by ignored objects. *Quarterly Journal of Experimental Psychology, 37A,* 571-590.

Treisman, A. M. (1969). Strategies and models of selective attention. *Psychological Review, 76,* 282-299.

Treisman, A. M., & Davies, A. (1973). Divided attention to ear and eye. In S. Kornblum (Ed.), *Attention and Performance IV* (pp. 101-117). New York: Academic Press.

Treisman, A. M., & Gelade, A. M. (1980). A feature integration theory of attention. *Cognitive Psychology, 12,* 97-136.

Treisman, A., Kahneman, D., & Burkell, J. (1983). Perceptual objects and the cost of filtering. *Perception & Psychophysics, 33*, 527-532.

Tulving, E. (1985). How many memory systems are there? *American Psychologist, 40,* 385-398.

Tulving, E., & Schacter, D. L. (1990) Priming and human memory systems. *Science, 247,* 301-306.

Tulving, E., Schacter, D. L., & Stark, H. A. (1982). Priming effects in word fragment completion are independent of recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 8,* 336-342.

Witherspoon, D., & Moscovitch, M. (1989). Stochastic independence between two implicit memory tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*, 22-30.

Weldon, M. S. (1991). Mechanisms underlying priming on implicit perceptual tests. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 526-541.

Weldon, M. S., Roediger, H. L., & Challis, B. H. (1989). The properties of retrieval cues constrain picture superiority. *Memory & Cognition, 17,* 95-105.

Wheeler, D. D. (1970). Processes in word recognition. *Cognition, 1*, 59-85.

Wilson, W. R. (1979). Feeling more than we can know: Exposure effects without learning. *Journal of Personality and Social Psychology, 37*, 811-821.

Winograd, E., Sebel, P. S., Goldman, W. P., & Clifton, C. L. (1990). Indirect assessment of memory for music under anesthesia. In B. Bonke, W. Fitch, & K. Millar (Eds.), *Memory and awareness in anesthesia* (pp. 181-184). Amsterdam: Swets & Zeitlinger.

Wippich, W. (1995). Priming on verbal perceptual tests: Role of lexical, surface, and conceptual processes. *Psychological Research, 57*, 250-259.

Wolford, G. L., & Morrison, F. (1980). Processing of unattended visual information. *Memory & Cognition, 8*, 521-527.

Wolters, G., & Phaf, R. H. (1990). Explicit and implicit memory measures of memory: Evidence for two learning mechanisms. In B. Bonke, W. Fitch, & K. Millar (Eds.), *Memory and awareness in anesthesia* (pp. 57-63). Amsterdam: Swets & Zeitlinger.

Wood, J. M., Bootzin, R. R., Kihlstrom, J. F., & Schacter, D. L. (1992). Implicit and explicit memory for verbal information presented during sleep. *Psychological Science, 3*, 236-239.