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Implicit Category Priming Capacity

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Walden University
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Abstract

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M.S., Walden University, 2010

B.S., University of Maryland, 1986

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Abstract

Past research has shown that accessing a memory allows faster subsequent access to the memory activated as well as to related information (*priming)*. There has been much research devoted to implicit category priming (unintentional priming of a category of information), but this research has not determined the number of categories that can be implicitly primed simultaneously. The goal of the present quantitative study was to address that gap. Twenty participants (ages 27-54 years, M=44 years), who volunteered through an online participant pool, were presented with 2 tasks over the Internet. A scrambled phrase task implicitly primed 5 unrelated categories and a lexical decision (LD) task measured the priming (mean time between tasks = 42 seconds). Resulting primed and unprimed LD response latency distributions were strongly, positively skewed, which obscured individual priming effects. Gaussian parameters were extracted to overcome this skew, and the distributions were created for analysis. Dunnett's multiple comparisons post-hoc test following a 1-way ANOVA showed that 2 of the 5 categories remained significantly primed. Follow-up research should determine the reliability of this value. This value, and its range (to be identified in follow-up studies) would provide a means for comparing lesson efficacy and teacher performance. The results of this research also replicate previous research demonstrating long-term implicit category priming.

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Chapter I: Introduction to the Study

Introduction

Accessing information in memory allows faster subsequent access to the information activated as well as to related information. Researchers have referred to this as *priming* (Winnick and Daniels, 1970). Several types of priming have been investigated, and imaging research suggests that these different types have in common an activation in a group or system of neurons that slowly decays (Bowden & Beeman, 1998; Faust & Chiarello, 1998; Faust & Kahana, 2002; Faust, Ben-Artzi, & Harel, 2008; Shears & Chiarello, 2003). These different types of priming have different characteristics and objects, and so they are treated separately by researchers.

Perceptual priming, sometimes referred to as repetition priming, occurs when a perceptual representation itself is activated by immediate sensory experience (Casale & Ashby, 2008; Jacoby, 1983; Squire, Ojemann, Miezin, Petersen, Videen, & Raichlem, 1992; Wiggs & Martin, 1998). This type of priming occurs in every sensory modality, but has been most often studied visually. In the visual modality, a perceptually primed object can be an image, shape or, if a word, the whole and/or the parts of the representation, such as its orientation and typography. The priming decreases the time required to recognize similar characteristics in a second image (Kircher, Sass, Sachs, & Krach, 2010; Wiggs & Martin, 1998). In its simplest or purest form, perceptual priming has no associates in memory; the activated pattern has no meaning.

Semantic priming results from the activation in memory of the meaning of a particular object, rather than simply a displayed form as in perceptual priming (Eder, Leuthold, Rothermund, & Schweinberger, 2011). Semantic priming occurs when a perception activates some internal association that provides meaning. This meaning is then recognized more quickly when it exists in a subsequent perception. Examples of semantic priming objects are particular items, such as my cat, that car, etc., as well as the meanings of words, for example, recognizing the word “rabbit” would activate words that mean “rabbit,” such as “bunny” and the word “mean” might also activate the word “vicious.” These words would then be recognized milliseconds faster when compared to the recognition times of other words.

Finally, c*ategory priming* involves the activation of a category of items in memory (Ray, 2008). It is more similar to semantic than perceptual priming, because its objects are meaning and associations. For example, the word *car* might prime the memory of an individual’s personal automobile, as well as other automobiles in general, the price of gasoline, the long ride taken with the family last month, as well as the frustration felt during a road construction delay during the trip. Each of the memories would be more quickly accessed for a short time following the priming. In a common experimental situation this would mean that response time for the recognition of associated words, such as *Chrysler* and *traffic,* would be shorter. This reduction in access time between related words and words unrelated would be interpreted as an indication of the strength of association between the priming and related target words (Fazio, Williams, & Powell, 2000).

Although no research has been found to provide evidence of this, it would seem that priming a category requires more energy and resources than priming references that have the same meaning, as in semantic priming, as a result of the number of memories, experiences, emotions, etc. that might be involved. Semantic priming capacity might be the capacity of short term memory, seven plus or minus two (Miller, 1956), but if priming capacities are limited by the energy and resources available (physiological structures for directing activities and information storage, available neurotransmitters, for example) category priming capacity would be lower.

Because no estimates of category priming capacity have been found in previous research, this research attempted to measure it. Again, no evidence has been found to support this, however, it seems certain that at least two categories can be referenced simultaneously, as in the common experience of comparing one category to another. For example, the decision to obtain an advanced degree might be made by weighing the amount of work required to obtain it compared to the usefulness likely to be obtained from it.

Developed abilities to reference and relate more than a single category would seem to be also necessary, for instance, for anyone interacting with a group of individuals with differing cultural, educational, and experiential backgrounds. It would also seem to be necessary in reading when some number of categories of information must be held in mind in order to build a context being developed by an author, or when understanding a lesson or report that encompasses a variety of fields of information, such as regression, factor analysis, some historical situation, or the results of a study that used a complex ANOVA design. While no research has been found that addresses this issue, it seems likely that the optimal development of category capacity and skills, like other cognitive abilities and skills, results from example and practice during education and from other experiences, and, once the skills are developed, like any other well-practiced set of skills, they would be employed automatically (Neely, 1977; Yin & Knowlton, 2006).

The potential for positive social change would result from providing an estimate of the capacity, which might be useful in future research to investigate the impact that higher and lower capacities in individuals might have in social situations, in education, and in the workplace. This knowledge could also lead to changes in educational procedures with lessons designed to enhance the capacity and possibly in the guidelines of lesson development.

This chapter will summarize research that has reported investigations into some of the characteristics of priming. In addition, definitions, a description of the problem studied, the study's nature, purpose, including a brief discussion of descriptions of priming, assumptions made in the research, the research design, and the study's limitations and significance was considered.

Background of the Study

Although there have been many studies investigating category priming, none have attempted to measure category priming capacity. Early research found that for a very brief time after an ambiguous word is encountered when reading, a number of meanings or categories of possible meanings are primed, and that this facilitation narrows to meanings that are appropriate to the context of the passage containing the ambiguous word after that brief initial period (Kintsch & Mross, 1985; Swinney, 1979; Till, Mross & Kintsch, 1988). Early research also seemed to indicate that category priming was brief and easily disrupted. For example, Balota and Lorch (1986) did not find significant category priming (although it was not termed *category priming*) in a third word primed by the first word of a word-triplet, when the second word was unrelated to the third. In contrast, McNamara (1992b) found that category priming (again, category priming was clearly tested, but that was not the term used in the report) was still evident after the priming of one unrelated word, but not after two unrelated primings. Following this, there were numerous studies that found that when a scrambled sentence task used multiple priming experiences to prime a category, such as a perspective, the priming was measurable several minutes after the priming task (Banaji, Hardin, & Rothman, 1993; Bargh, Chen, & Burrows, 1996; Epley & Gilovich, 1999; Kawakami, Dovidio, & Dijksterhuis, 2003; Kûhnen & Hannover, 2000; Lepore & Brown, 1997; Randolph-Seng & Nielsen, 2007; Shariff & Norenzayan, 2007; Srull & Wyer, 1979).

Referring to the earlier work in which category priming was found to be brief, Ray and Bly (2007) primed six categories of information with 10 sequentially presented priming experiences each, and then tested the priming of the first three. They found significant priming in those three categories, showing that category priming was maintained during the priming of three other categories. Although research has not specifically investigated category priming capacity, results obtained by Ray and Bly (2007) and Hines, Czerwinski, Sawyer, and Dwyer (1986) demonstrated that category priming capacity is at least three. Based on those results and considerations discussed in Chapter III, five categories were primed and tested in the study reported here.

As will be shown clearly in Chapter II, although researchers have investigated many aspects of category priming, implicit category priming capacity has not yet been measured or considered in published research. Descriptive statistics from standardized tests of other individual difference measures have proven useful to education, for example (Camara & Schmidt, 1999). I attempted to determine this missing, possibly key, individual difference measure, providing those in helping professions with another individual difference which might be useful in understanding and helping those who benefit from their efforts.

Problem Statement

The aim of the research presented here was to determine the number of categories of information that can be primed. Based on studies that have primed affective and cognitive styles and social behavior, Ray and Bly (2007) questioned the conclusions from early researchers that priming was fragile and brief, and showed that three categories of information could be primed and that the priming was maintained while three unrelated categories of information were primed. As has been previously stated, no published research and no researchers, to this candidate's knowledge, has investigated or considered implicit category priming capacity (or any category priming capacity). Some of their findings, though, have raised the question of what implicit category priming capacity might be, and so the reported research attempted to determine it. Determining the mean and range of this value would likely then lead to correlational research between educational, social, and occupational performances, and the results of these could be useful in education and occupational training programs.

Purpose of the Study

Priming has been defined in past research as the effect of accessing information in memory in one task on the latency of accessing the same or related information in a following task (e.g., Ray & Bly, 2007). Utilizing this procedure, this research provided priming experiences for five categories of information to individuals and then measured the number of these categories successfully primed using a lexical decision task. The number of significantly shorter lexical decision mean response latencies between words from each primed category and the unprimed words were expected to be the number successfully primed for each participant. This would have required five comparisons for each participant, which was made using one-way Analysis of Variance. The Results Chapter will explain why this part of the analysis was not conducted.

Nature of the Study

The design selected provided a means to determine the number of categories successfully primed in each participant, which would have produced the mean number of categories and the range for the entire group. The independent variable was the relatedness of the words in the lexical decision task to the categories primed in the scrambled phrase task. The words were either unrelated to any of the five categories or they were related to them. The dependent variable was the response latencies from the lexical decision, word-nonword decisions. The sample of participants were volunteers from Walden's Participant Pool. The two tasks (scrambled phrase [priming task] and the lexical decision task [which measured the priming]) were presented over the Internet using the programming languages HTM and JavaScript to present the tasks, and Perl to receive the data provided by participants, and also to present every page after the first. Participants used their own computers, or one of their choosing, to complete the tasks, and the data was sent to an Internet server (a hosting server), downloaded and analyzed using the Statistical Package for the Social Sciences (SPSS), one-way Analysis of Variance procedure.

Conceptual Framework

Researchers have theorized about the psychological processes involved, for instance, in the way associations propagate beyond some initial focus (Collins & Loftus, 1975; McNamara, 1992a; McNamara, 1992b; McNamara, 1994). This extended group of associations is considered a category in the present research. Also related is the description of the levels of processing described and investigated by Craik and Lockhart (1972), as described and cited by Craik and Tulving (1975). According to their theory, greater semantic involvement of material will lead to stronger, more resilient memories. Craik and Tulving found this in their research. The scrambled phrase task used in the research reported here took this into account by having participants interact with the priming words semantically to create meaningful phrases which construct a context, priming a category of information. This process also involves Schulman's (1974) principle of congruity, which requires that an integrated whole is needed for the strongest memories to be formed, as demonstrated by the stereotyping research, as well as the research using word-triads with varied congruity of meaning. Creating the meaningful phrases, using 10 consecutively presented priming experiences, created that congruent concept in the minds of participants, creating context and activating categories, decreasing the time required for the identification of related words presented in the lexical decision task, which immediately followed.

Definition of Terms

Relatedness

Relatedness refers to the relationship between the words in the lexical decision task and the five categories primed in the scrambled phrase task. There were two conditions: related and unrelated. The related and unrelated words used in the study were taken from the Nelson, McEvoy, and Schreiber (2004) free association database. Related words are associates of the categories selected and unrelated words are not related to the category labels or any of their associates.

Lexical decision response latency

Lexical decision response latency was the dependent variable. This is the time, in milliseconds, from when a word is displayed until the participant presses the *w* or *n* key to indicate whether the letter-string is a word or not a word (nonword). Lexical decision response latency was shorter in the related condition, which indicated that priming has occurred.

Category

For this research, a category is the group of memories associated with a perceived stimulus, which are automatically activated in memory when an associated word is read, and a priming context phrase is created, in the scrambled phrase task.

Priming

The increased activation of a memory or concept as a result of a previous experience of conceiving or perceiving something with which it has some similarity or commonality (Winnick & Daniels, 1970).

Semantic priming

A perceived meaning activates words with similar meaning. For example, when telling someone about a medium size ship and the words “boat” and “ship” both occur to them (Ray, 2008).

Category priming

A reference to a category activates the category and its associates (Ray, 2008). For example, when someone suffering from Post Traumatic Stress Syndrome (PTSD) perceives an object that activates the fears that that caused the PTSD, or when someone says “flask,” and one individual thinks of alcoholic beverages and another thinks of chemistry.

Research Questions and Hypotheses

For what number of primed categories would the mean lexical decision response latencies be significantly shorter than the mean lexical decision response latency of words unrelated to the primed categories, for each participant?

The null hypothesis was that significant differences between the mean lexical decision response latencies between primed (related to the primed categories) and unprimed (unrelated to the primed categories) words would not be found, within each individual’s performance.

The alternative hypothesis was that significant differences would be found between some number of the mean lexical decision response latencies for words associated with the primed categories (Rrl) and the mean lexical decision response latency for the words unrelated to the primed categories (Url).

H0: Rrl = Url, for each related mean (Rrl).

H1: Rrl < Url, $\alpha = .05$. for some number of related means

No evidence has been located that provides a clear indication of implicit category priming capacity. A common category priming experience might be when the extent of two different dimensions is compared. For instance, does some item's quality justify its higher price over an otherwise similar item? At times these comparisons can be difficult, which might indicate a capacity is reached. This could indicate that two might be the mean category priming capacity. Another tenuous piece of evidence might be the average number of meanings for homonyms. A perusal of cue associates in the Nelson, McEvoy, and Schreiber (2007) database suggests that that number is two, although, in listing items in a description, three seems satisfying; e.g., "were always helpful, welcomed, and much appreciated". Another indication might be found in the results of Ray and Bly (2007), whose results appear to have demonstrated the priming of three categories, and an interpretation of the results of Graf, Shimamura, and Squire's (1985) second experiment could indicate that only a single category had been primed. Exemplars selected from three categories (Battig and Montague, 1969) were studied by participants, than they were given six category labels (three had been primed) and asked to produce as many items within the categories as they could. Only primed words were counted, not all associates or exemplars from Battig and Montague of each primed category, but healthy participants produced only 5% of the category words studied. That could indicate that less than one category was primed, and this could indicate that priming more than one category takes a little extra effort. Finally, evidence from Hines, Czerwinski, Sawyer, and Dwyer (1986) is also tenuous. In their second experiment, each participant's average tachistoscopic recognition duration was determined, then tachistoscopic recognition durations for 20 primes (line drawings of the first and fifth exemplars from 10 categories from Battig and Montague (1969), were found. Following this, participants were forced to name each image presented at their individual mean tachistoscopic recognition duration. The group was divided into high and low halves based on the number correct. The low group mean was 13% correct and the high group mean was 33%, which might translate into 1.3 and 3.3 categories, respectively (10 categories * .13, etc). In their experiment, Hines, et al. used line drawings of exemplars and the priming was explicit (the images were named), so it is not a very good parallel to the experiment used in the research reported here, but it does seem to provide values for priming capacity. All of these potentially associated pieces of evidence and guestimates provide only very vague indications of implicit category priming capacity, but they suggest that three might be a high average.

Assumptions

Because the tasks that were used were simple, and very similar tasks have been successfully used by previous research, they were expected to produce and measure priming. It was also assumed that the number of categories primed would be greater than the category priming capacity to be measured.

Another assumption is that a scrambled phrase task would produce a priming effect as scrambled sentence tasks have in previous research. No research located has used phrases rather than sentences, but a context to identify a particular category of meaning for each priming word is created by unscrambling the phrases, and the time required to unscramble the phrases seem similar, so interacting with category associates using this technique was expected to produce similar priming also.

Limitations

The reported research was not able to compare capacities of different word-types, such as verbs and nouns. Only nouns were to be used as primes, so that each category is similar to the others; the units have some similarity, so to speak, although it is not known if this was necessary. In addition to this, the participants were not representative of the general population, because only individuals in Walden's Participant Pool would have an opportunity to be involved. While there was no reason to believe that these individuals would be substantially different from individuals in the general population, their education was higher, and so the results might only be applicable to individuals with higher education.

Scope and Delimitations

The research attempted to measure the number of categories of information for which an initial access to the categories in memory reduced the time required to access the same categories of information in a following task. I expected that this measure estimated the number of categories of information that individuals can keep in mind simultaneously, for instance, during an evaluation of a situation and in understanding complex analyses.

This topic was chosen after reading studies in which some number of categories was primed, and a reference to a mean category priming capacity would have been reasonable, and potentially necessary, for a more complete understanding of the results, but was never considered by the authors. These experiences followed others, occurring during earlier academic experiences, in which some number of categories of information needed to be simultaneously held in mind when understanding or considering the ramifications of a statistical analysis, such as factor analysis or regression analyses, and it was noticed that others discussing the analyses seemed to only consider one or two variables at a time. Finally, while considering topics for this dissertation, a search was made in the literature, and no reference to this individual difference was found.

The group of individuals were volunteers from Walden University's Participant Pool. The main difference between this population and the general population was their educational level. As a result of this difference, category priming capacity was expected to be higher in this group than in the general population, due to their experiences considering and describing research and other relatively complex topics presented to them during their coursework.

Significance of the Study

This study attempted to measure category priming capacity, hopefully providing information that will allow educators to not only keep the number of categories presented during lessons within capacity limitations, but also to possibly lead to research into strategies to increase and develop this capacity in students. Once the value and range of implicit category priming capacity is known, occupational researchers should correlate measures of this with performance in various occupations to determine its impact, if any. Education might benefit from research into learning using various numbers of categories presented in educational lessons and tests to determine if an ideal number exists or if this value changes with grade level, for instance.

Positive Social Change

Increasing our understanding of the limitations and capacity of category priming could help educators and researchers develop improved educational strategies that take full advantage of student capabilities without unknowingly exceeding their limitations, improving the educational experience of students and potentially increasing the effectiveness of educational methods. Knowledge in this area could lead to the development of simple psychometric instruments that could provide improved guidance to educators for individual students, help in the selection of textbooks, and in the development of lesson plans.

Summary

The introduction presented provided a summary of related past research. The more detailed history of previous research to follow will demonstrate that although the investigation of category priming has followed complex subtopics, and delineated fine details that have added greatly to the understanding of this process, the question of capacity has thus far been ignored. Following a literature review in Chapter II, Chapter

III will report the Research Method to be used, Chapter IV will report the analysis and results of the research, and Chapter V will report the conclusions that were drawn.

Chapter II: Literature Review

Introduction

The study reported here attempted to determine the implicit category priming capacity in a participant group. Implicit category priming capacity in this research was considered to be the number of unrelated categories of information that can be primed, using a scrambled phrase task in which 10 phrases created by each participant primed each of five categories. The number of successfully primed categories was measured using a lexical decision task. The mean and range of these values in the group constituted the main results of the study.

Research has discovered that retrieval of information from memory using brief tachistoscopic durations results in brief priming (e.g., O'Neill, 1956; Rouse & Verinis, 1962; Winnick and Daniel, 1970), and priming that could be easily disrupted (Balota & Lorch, 1986; Joordens & Besner, 1992; Masson, 1995). But research priming affective, social, and cognitive responses has found that longer or multiple access to information being primed provides more resilient priming (e.g., Bargh, Chaiken, Govender, & Pratto, 1992; Casper, Rothermund, & Wentura, 2010; Corcoran, Hundhammer, & Mussweiler, 2009; Fazio, Sanbonmatsu, Powell, & Kardes, 1986; Kawakami, Dovidio, & Dijksterhuis, 2008; Kiefer & Martens, 2010; Kûhnen, Hannover, & Schubert, 2001; Kûhnen & Oyserman, 2002; Kûhnen & Hannover, 2000; Lemaire, Barrett, Fayol, & Abdi, 1994; Was, Paternite, & Wooley, 2008). Early priming research focused on priming single categories at a time, but research has also provided indications that psychological functions exist that use multiple categories of information to solve problems in which the solution is not immediately clear (Kintsch & Mross, 1985; Till, Mross, & Kintsch, 1988; Swinney, 1979), and, supporting these findings, physiological research has demonstrated that the left hemisphere is central when solutions require single categories of information, and the right hemisphere when multiple categories must be considered (Bowden & Beeman, 1998; Faust, Ben-Artzi, & Harel, 2008; Faust & Chiarello, 1998; Faust & Kahana, 2002; Shears & Chiarello, 2003; Whitney, Grossman, & Kircher, 2009). Research has not investigated the number of categories that are typically, implicitly primed, but has provided indications that three categories of information might be a close to the upper end of the range (Hines, Czerwinski, Sawyer, & Dwyer, 1986; Ray & Bly, 2007).

This chapter will provide more in-depth summaries of related research that led to this investigation, covering the earliest findings, and findings from general research on associations, followed by a narrowing to the more closely related studies concerning resolving ambiguity in reading. Related physiological research will be summarized, followed by research investigating factors influencing semantic and category priming, the priming of affect, social perception, and cognitive responses. Finally, the question of priming capacity and the techniques employed in the research reported here will then be considered.

The first search for past research for this review made use of scholar.google.com, using the search term “priming categories,” was conducted on January 20, 2011, and returned 43 items. In April, 2011, priming research that used the scrambled sentence task was located similarly to help decide if that task would be useful in the research. These searches, and the literature reviews in these articles, guided this review until mid-July 2011, when a new round of Google searches was undertaken, as the writing of this review began in earnest on July 16, 2011, and the most recent research was needed to provide a more complete review, and to ensure that the question asked had not been answered. During this series of searches, *semantic priming* was considered the topic, and the results of *semantic priming capacity* were expected to provide the most relevant material, but none of the 24 articles it located actually involved *semantic* or *category priming capacity* as it is meant in this study. In the few that did, *capacity* simply referred to the ability to prime; the effectiveness of priming techniques.

Research uncovered spanned a period from the 1940s (Bousfield & Sedgewick) to 2011 (e.g., Leuthold, Rothermund, & Schweinberger), and research articles are predominantly from peer-reviewed journals (American Journal of Insanity, Behavior, Behavior Research Methods Instruments & Computers, Brain, Brain and Cognition, Brain and Language, Cerebral Cortex, Cognition, Cognitive psychology, Current Biology, Current Opinion in Neurobiology, European Journal of Social Psychology, Experimental Psychology, International Journal for the Psychology of Religion, Journal of Abnormal Psychology, Journal of Cognitive Neuroscience, Journal of Experimental Child Psychology, Journal of Experimental Psychology, Journal of Experimental Psychology Monograph, Journal of Experimental Social Psychology, Journal of General

Psychology, Journal of Personality and Social Psychology, Journal of Memory and Language, Journal of Neuroscience, Journal of Verbal Learning and Verbal Behavior, Laterality, Memory & Cognition, Neuropsychologia, Perception & Psychophysics, Proceedings of the National Academy of Sciences USA, Psychological Review, Psychological Science, Scan, Science, Social Psychology, The Journal of Abnormal and Social Psychology, Trends in Cognitive Science), with most from the Journal of Experimental Psychology, and a few references from texts and internal university publications.

Conceptual Framework

Semantic and category priming are closely related in priming research. Semantic priming is the priming of a single meaning. For example, someone's name will bring to mind that person to someone who knows them. Category priming is the priming of a category, such as the word *fruit* brings to mind, primes, fruit, such as *apple* and *orange*, and possibly other related concepts such as *sweet*.

One difficulty encountered during research for this review was that semantic and category priming have not always been differentiated clearly in research, they are often interchangeable terms, or other terms are used that include both. Tulving and Schacter's (1990), for instance, discuss "Perceptual Versus Conceptual Priming" (p. 304) and McNamara's (1992a) refers to them with "associative priming". Balota and Lorch (1986) tested the spreading of activation in semantic space with category priming. Becker, Moscovitch, Behrmann, and Joordens (1997) is another example. The title of their report is “Long-term semantic priming: A computational account and empirical evidence,” but they use category-norming exemplars and are clearly working with category priming. Ray (2008) differentiated the two when describing results from another report.

> Low semantically similar exemplars in a category demonstrated the category-priming effect through priming of the category (i.e., exemplar–category–exemplar), whereas high semantically similar exemplars in the same category demonstrated the semantic-priming effect (i.e., direct activation of one high semantically similar exemplar by another). (p. 134)

This differentiation is meaningful in a study such as the one reported here, in which categories have been identified that have associates which share minimal overlap in meaning. However, as a result of the undifferentiated use of the two types of priming by researchers, articles investigating each were found to be useful sources of information.

Findings from Early Priming Research

The first priming research might be considered to be a study reported by Greenwald, Draine, and Abrams (1996) of subliminal perception of semantic information that was published in 1884 by Pierce and Jastrow, but modern research seems to have begun with a category priming study that used free association, reported in Bousfield and Sedgewick (1944), or with another category priming study reported in Winnick and Daniel (1970), who seem to have been the first to apply the term *priming* to describe the facilitation of access to associated information in memory by prior experience.

> Rouse and Verinis (1962) found lowered thresholds for words following exposure to their associates compared to controls. Here, exposure to a word created a set to respond not just to that word, but to associatively related words as well. …it seems unnecessary that a particular word be seen for it to show an advantage in tachistoscopic recognition; more important may be the activation of implicit responses of saying the word or related words …. The term "priming" has been used in another context to refer to similar response activation and might also be appropriate here. (Winnick & Daniel, 1970, p. 74).

Generally, early priming research moved from free recall to tachistoscopic recognition times to sentence comprehension and then to the priming of larger responses, and psychological sets; early priming tended to focus on the process of priming, while later research provided examples of how priming from everyday experiences, for instance as found in by mass media, games, and peer groups, probably shapes our social and cognitive responses, such as our attitudes and perspectives. Both semantic and category priming have in common associations between objects and meaning, and some of the earliest research in the field investigated this. There have been parallel lines of research occurring, with free association and tachistoscopic recognition studies of priming continue up to the present. Findings from early research on semantic priming identified some of its basic characteristics, while its physiology was investigated and theoretical accounts were proposed beginning in a middle period. More recently, some of the finer details of priming are being uncovered.

Early studies of association have provided the conceptual framework for studies of category priming. For instance, Bousfield and Sedgewick (1944) found a function that fit the course of free association production, making free recall production rate predictable, and identifying a parameter that a complete model of semantic and category priming would have to meet. Early research investigating priming with recognition, with comparisons of tachistoscopic recognition times of related and unrelated words (e.g., O'Neill, 1956; Rouse & Verinis, 1962; Winnick & Daniel, 1970) demonstrated that priming increases the probability that associated items will be recalled together, that words associated with a prime are recognized more quickly than unassociated words, that efferent associations occur more frequently than afferent associations in recall, and that afferent associations produce the shortest response times, which might reflect the common process of categorizing a perceived object. Each of these studies demonstrated that a category can be primed by presenting only some of its items.

Jenkins and Russell (1952) investigated types of associations (efferent and afferent) within a list of memorized words. Using words from a free association study, they found that when words are memorized in no particular order, as they are recalled, associated words are recalled together, as the first word apparently primes the second. Associations produce organization.

O'Neill's (1954) study demonstrated clearly how a priming word influences perception. He provided the example of a participant who repeatedly guessed *camel* to the tachistoscopically presented *candle*, with the priming word *thirsty* steadily presented on the screen. The difference between related and unrelated recognition times (RT) was significant in O'Neill's research, even though there were only nine participants. O'Neill also compared RT between efferent and afferent associations, and found that afferent associations had shorter RT than efferent associations (1.250 vs. 1.303sec), although the difference was not significant. Rouse and Verinis (1962) replicated those findings with 0.062 vs. 0.073sec (again, not a significant difference with only 11 participants), and 0.093sec for unassociated words. Winnick and Daniel (1970) demonstrated category priming by presenting some of the names of the U.S. states to participants, and then compared the tachistoscopic recognition times of the state names they had primed, state names they had not primed, and unrelated words, and found that both primed and unprimed state names recognition was facilitated, compared to unrelated words, demonstrating that category priming had occurred.

Tulving (1962) also found that individuals apply a semantic organization to recalled information, conducting a highly complex analysis, replicating the findings of Jenkins & Russell (1952). These findings raised questions about the form and content of stored memories. Tulving and Thomson (1973) used the term "encoding specificity principal," to refer to a retrieval model for episodic memory in which the context is encoded as part of a memory, "What is stored is determined by what is perceived and how it is encoded, and what is stored determines what retrieval cues are effective in providing access to what is stored" (p.353), and "what is stored about the occurrence of a word in an experimental list is information about the specific encoding of that word in that context in that situation" (p. 359). When a word is remembered, contextual information, along with situational variables that happen to be present, become part of the encoded object, referred to as a compound. This idea would become part of a controversy involving the way in which associations spread in semantic memory (see Collins & Quillian; 1970; Ratcliff, 1978). A series of interesting experiments investigating ambiguous words would later produce interesting evidence related to this spreading activation versus compound cue controversy, although it did not seem to enter the controversy formally.

Priming Multiple Categories

Although past research has provided much information about priming, limitations of designs and strategies prevented results from showing the number of categories primed.

Resolving Ambiguity

Swinney (1979) presented a cross-modal study which investigated events involved in determining the meaning of an ambiguous word encountered in a sentence, testing if the initial phase of meaning selection is an autonomous process or determined by the context of the sentence.

In Swinney's first experiment, participants made a word-nonword lexical decision (LD) of a visually presented letter-string which was displayed immediately following an ambiguous word in a sentence, auditorily presented through a headset using a tape recorder. Lexical decision words (all nouns) were either ambiguous, having two meanings which were approximately of equal efferent strength, one of which was related to the context of the sentence[1], or the words were unrelated to the sentence context, or they were nonwords. A pilot study with the LD words had shown that the words and nonwords used had response latencies that were not significantly different from one another, $F(2, 46) = 0.918$.

Using a complex design, Swinney (1979) included seven participants in each of 12 counterbalanced experimental conditions involving contextual and ambiguity variations in the sentences in addition to the three word conditions. Data was analyzed by an ANOVA design divided by ambiguity (ambiguous vs. unambiguous), sentence context (biasing context vs. no context), and LD word contextual relationship (related vs. inappropriate vs. unrelated). Results included significant main effects, and comparisons showed that the LD response latencies of words that represented both contextually appropriate and inappropriate meanings were significantly faster than words with meanings that were unrelated to the sentence contexts, $t(83) = -6.1$, $p < .0009$; $t(83) =$

[1] For example, *iron* might refer to either the metal or to a device used to remove wrinkles from clothes.

-5.04, *p* <.0009. An important aspect of this research was the timing of the presentation of the LD word. It was presented immediately following the ambiguous word in the auditorily presented sentence.

In Swinney's (1979) second experiment, the time-course of appropriate meaning selection was investigated. This experiment was a replication of the first experiment, except that the LD was presented three syllables after the ambiguous word in the, this time, visually presented, one word at a time, sentence. The sentences were also changed. Textual passages containing the ambiguous words were presented in single sentences instead of two-sentence paragraphs, and half referenced the efferently strongest meaning of the ambiguous word, while the other half referenced the weaker of the two categories of meaning. Also included in the experimental task were eight filler sentences, which also involved a lexical decision, and 32 sentences for which nonwords were displayed. Analysis showed that, when the LD was presented three syllables after the ambiguous word, only the LD response latencies of the appropriate meanings were facilitated.

These two experiments provided evidence that when an ambiguous word is confronted in a sentence, both inappropriate and appropriate meanings are initially facilitated, followed, after just three syllable or less, by only facilitation of the appropriate meaning. These results provided evidence that the initial phase of meaning selection of an ambiguous word is, initially, an autonomous process, not influenced by the context of the sentence in which the ambiguous word appears.

Both theories which attempted to describe how associations propagate, in the controversy mentioned at the beginning of this section, spreading activation and compound cue, might have a difficult time accommodating these results; stages would have to be included to both theories. A movement from category to semantic identification clearly occurs. Accommodation for a sequence that Kintsch and Mross (1985) later described as consisting of *sense activation* (multiple category access or priming), *sense selection* (category priming, category selection), and *sense elaboration* (when the context of a sentence or passage fine-tunes the meaning of an ambiguous word) processes would have to be included. Evidently, the spread of association through memory begins with, and/or somehow involves, accessing multiple categories of information, narrowing down possibilities if a defining context is available, and then, using the concept that has been selected (constructed?), associations are made in the sense elaboration phase in the Kintsch and Mross (1985) model. A spreading activation-compound cue sequence model might be reasonable, but either by itself seems inadequate in light of these findings.

In the report I summarized, Swinney (1979, p. 653) stated that “immediately following occurrence of an ambiguous word all meanings for that word seem to be momentarily accessed during sentence comprehension”. It might also be reasonable to speculate that the number of categories that would be primed by each participant might be related to the individual’s category priming capacity.

Kintsch and Mross (1985) replicated Swinney's first cross-modal experiment findings, again using paragraphs and an LD task to measure priming, and using a complex design. These researchers used words in which the relationship between the priming source (word or paragraph context) and target word was more accurately known from associative proportions provided by a free association study, and they lengthened the paragraphs in their first experiment. In half of the paragraphs, priming came from a single word, as in Swinney's experiments, referred to as the homograph test in the report (because each written word had multiple meanings), and in the other half the source was thematic. In this *Scripta*l condition, the evolving context of the paragraph provided the prime. This Scriptal condition consisted of 12 paragraphs that described occurring activities. The words used for the LD task for these paragraphs were not given as associates to target words. Instead there were three conditions, some of the words were procedurally associated, some were strongly associated with the themes (contexts), and some were unrelated control words. They provided an example for one paragraph that involved someone going through the process of going to an airport, buying a ticket, and so on. At the point where that person would be going to the gate, the word *gate* was displayed, or an associated word *fly* was displayed, or *STACK* for the unrelated word. In the Homograph condition, the LD words displayed for the passages were, like Swinney's, words that had reasonably strong efferent associations from the last word heard in the paragraph (target). Also as in Swinney's research, the target words had two possible meanings, one related to the context of the paragraph, and the other not: appropriate and inappropriate meanings. There were 12 homograph paragraphs in the Homograph condition. In half of these, the stronger of the two efferent associations was primed, and the weaker of the two associations was primed in the other half. Results showed that significant priming effects occurred for both the Homograph and Scriptal conditions, $F(2, 67) = 4.04$ (by participants) and $F(2,33) = 10.01$ (by texts: associated/thematic, associated/non-thematic, and control) for the Homograph condition, and for the Scriptal condition, $F(2,67) = 6.00$ (by participants) and $F(2,33) = 4.74$ (by texts: unassociated/thematic, associated/mixed, and control). In the Scriptal condition, facilitation was greatest for the associated word *fly;* the word that was associated to the overall theme of the paragraph, rather than *gate*, which was associated with the next procedural step.

The second experiment reported by Kintsch and Mross (1985) was the same as the first, except that paragraphs were presented visually, as in Swinney's (1979) second experiment. Priming effects for the two experiments are difficult to compare. Interestingly, though, the greatest priming effect was found in the cross-modal associated/mixed condition (*fly* again), otherwise, effects were greatest, compared to controls, in the unimodal experiment (see their Table 2, p. 28), as has been found in other cross-modal priming research (Graf, Shimamura, & Squire, 1985; Schneider, Engel, & Debener, 2008).

Till, Mross, and Kintsch (1988) replicated their earlier experiments as well as Swinney's (1979) findings, but measuring timing more precisely. In their first experiment, at 333ms both homograph meanings that were both appropriate to the sentences and inappropriate showed significant priming, as in Swinney (1979) and Kintsch and Mross (1985), while only appropriate meanings were primed at 1000ms. In their second experiment, their task presented LD words 300ms, 500ms, and 1000ms after an ambiguous word, and demonstrated that during reading, category priming occurs during the first half-second or so when an ambiguous word is encountered. The context of the passage had no measurable impact on facilitation during this brief initial period, and LD response latencies of word meanings that were related to the target word in the passage, both appropriate and inappropriate to the context of the passage were facilitated. Their research also found that by one second after the ambiguous word was encountered, priming of only meanings appropriate to the context of the passage remained facilitated.

Evidence for separate processes for multiple category access and single category access has also been found in physiologically focused priming research, but researchers did not relate this to their findings in their reports (although Till, Mross, and Kintsch (1988) was included in Faust and Chiarello's (1998) references without citing the study in the report itself.).

Hemispherical Laterality

Priming researchers have used techniques that allow them to determine which hemisphere of the brain processes information, for example by presenting priming and target words to the right or left visual field (left or right hemisphere, respectively), and which parts of the brain in general process information, using EEG, fMRI, and PET.

Using these techniques, priming researchers have found that when an object, such as a word or image, is associated with a single meaning, processing in the left hemisphere is quickest, and when the category of meaning is not certain, and presumably multiple categories must be considered, processing in the right hemisphere is the quickest. In both cases, *quickest* means that priming effect is greatest and recognition times are shortest. As Shears and Chiarello (2003, p. 1), described it:

> In the left hemisphere, the meanings of target words, which are closely related to word primes, are activated quickly. This left hemisphere process may be accompanied by suppression of other, more distantly related meanings, while in the right hemisphere word meanings are activated more slowly and less selectively, maintaining the availability of more distantly related meanings.

Researchers have used very interesting procedures and paradigms to study this. For example, participants in the study reported in Bowden and Beeman (1998) solved insight problems, then read aloud solution and unrelated words presented to their left visual field (LVF-right hemisphere) or right visual field (RVF-left hemisphere). The insight problems consisted of three presented words to which the participant was to find a fourth word which could be coupled with each of the three to make three new words "(e.g., pie | luck | belly – pot)" (p. 436). The trials began with a 15sec period during which the participant was to try to solve the problem, this was followed by a tone, then a fixation cross, then either a solution word or an unrelated word was presented for 180ms either 1.5^{o} to the right or left of center, which the participants read aloud. Latency times, from when the word was initially presented until their saying it aloud, for solution words were shorter when presented to the right hemisphere. Their results indicated that the right hemisphere is involved in processes that require considering a number of solutions, or, phrasing it from the perspective of this proposal, processes that require considering solutions from a number of categories of information.

Faust is another researcher who has conducted a series of investigations into priming differences in the hemispheres. Faust and Chiarello (1998) found that the LD (word-nonword) response latencies (RL) of ambiguous words, associated with a previously presented incomplete sentences, were shorter when presented to the left visual field (right hemisphere), and the LD RL of words in which the meanings were clear in the incomplete sentences were shorter when presented to the right visual field (left hemisphere). Faust and Kahana (2002) conceptually replicated this by presenting word-triads to participants in which the dominant meaning was congruent among the three words, their subordinate meaning was congruent, or the meaning levels were mixed. A LD target word followed, in either the right or left visual field, and, again, the left hemisphere RLs were shorter in the congruent priming condition and the right hemisphere RLs in the incongruent priming condition. Faust, Ben-Artzi, and Harel (2008) studied this using a technique from false memory research, initially created by Deese (1959), possibly based on extralist cueing research that had been published around that time (use of cues to aid recall of list words where the cue was not a member of a memorized list of words, but was associated).

Deese was investigating false memories of a memorized list words, and had demonstrated category priming while investigating false memory in a word list paradigm in which participants were asked to remember lists of verbally presented associates of categories, from the Kent and Rosanoff (1910) norms, and then asked to indicate which words in written lists, which included the category names, they had heard in the auditorily presented studied lists. Results showed that the category names were often falsely remembered as items presented, as, apparently, the lists containing the associates had primed the categories, and the category names, which were incorrectly thought to have been in the lists, were primed also, similar to the findings of Winnick and Daniel (1970) using U.S. state names, and similar to the technique to be used in the research reported here, except that in Deese's research was cross modal and explicit priming was used, bringing attentional and intentional strategies into the process. Roediger and McDermott (1995) used this technique, which became known as the Deese-Roediger-McDermott paradigm (DRM), first to replicate Deese's findings, and then expand them to determine if participants believed they actually remembered the presentation of each word judged to have been in the auditorily presented lists or they were certain that the words were on the lists but did not actually remember them being presented.

Faust, Ben-Artzi, and Harel (2008) used this technique in a divided visual field experiment and found that when participants were asked to decide if ambiguous words, with meanings related to words that had been previously studied in auditorily presented lists, had been presented. Again, the right hemisphere RLs were shorter for ambiguous words (category names) and the left hemisphere RLs for words that had been on the list. The auditorily presented lists either consisted of associates of the dominant meaning of the category name presented later in the recognition test, or the subordinate meaning. Dominant meaning lists produced the greatest number of falsely identified category names, but subordinate meanings produced a greater number of falsely included category names when the name was presented to the right hemisphere, demonstrating again that the left hemisphere does the processing when the most certain meanings apply, and the right hemisphere, when there are alternatives to consider.

This processing that the right hemisphere seems to specialize in appears to be the same as occurred in the Swinney (1979), Kintsch and Mross (1985), and Till, Mross, and Kintsch (1988) studies during the initial period after an ambiguous word was presented in a sentence. That process occurred during the first half-second following the presentation of the initial word. This type of processing appears to be automatic, judging from the timing of its occurrence, which was immediately after the ambiguous words were presented in the Kintsch and Mross (1985) study; far too little time, it would seem, for participants to initiate an intentional search, activating multiple categories of information.

It is interesting that the description that Shears and Chiarello (2003) gave of right hemisphere processing as slow to activate seems inaccurate in light of the studies I have described that have found that the processing occurs within the briefest milliseconds after an ambiguous problem is encountered. Automatic processing would seem to be the fastest, with conscious processing acting as a sluggish final decision maker.

Showing the complexity involved in the brain's information processing systems, Whitney, Grossman, and Kircher (2009) compared fMRI measured activations between ambiguous and unambiguous conditions using word-triplets, and found areas in the right thalamus and right retrosplenial cortex (BA 30, see Figure 1) "were significantly stronger and exclusively activated for unambiguous relative to ambiguous double related trials … No other brain area showed stronger BOLD signals for unambiguous compared with ambiguous conditions" (p. 2553). As a result of previous findings that have shown that the right hemisphere produces longer RLs to unambiguous stimuli, the activity occurring in this area is perplexing. Whitney et al. also found that areas in the left prefrontal cortex showed the strongest differences for ambiguous conditions.

Intriguingly, Whitney et al. also found that an area in the right anterior cingulate cortex, commonly found to be active during conflict resolution (Botvinick, Cohen, & Carter, 2004; Oltman, Goodenough, Witkin, Freedman, & Friedman, 1975; Pardo, Pardo, & Janer, 1990; Roelofs, Turennout, & Coles, 2006), showed increased activation in the ambiguous conditions prior to target word presentation (see their Table 3).

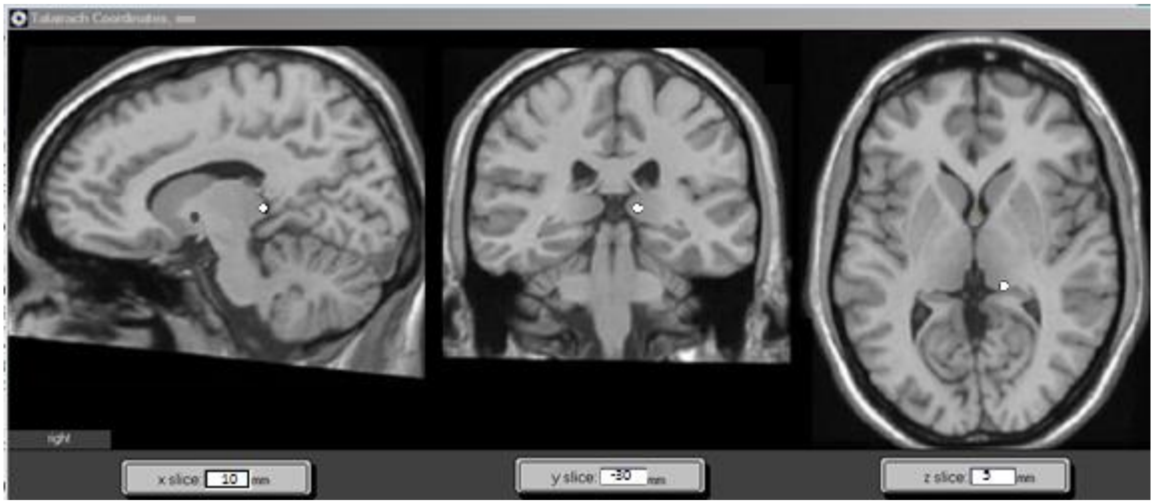

Figure 1. Location of right hemisphere activity from unambiguous triplets.

Note: Approximate location of right hemisphere activation stronger for unambiguous triplets in Whitney, Grossman, and Kircher (2009). (Candidate produced image, based on coordinates reported in their Figure 2.)

Category Norming and Free Association Studies: Defining Category

Priming, then, when meaning is not clear, seems to involve access to multiple categories of information initially, then, when a meaning is identified that is congruent with information available, a single (category) target remains primed (priming is maintained for one category, or other categories are inhibited), as in the automatic search involved in the identification of ambiguous words. In many studies, a word is presented and the participant, presumably, identifies it, and provides some type of response. It seems possible that in these types of ambiguous situations, in which there might be no information to guide an identification of meaning, the final result can be a field of associations, a field of categories, such as in studies where category norms are gathered or in free association studies where a single associated word is the required response. The word *jam*, for instance, has more than one category of meaning, because it might refer to a sweet spread that might be good on a peanut butter sandwich or a movement blocking condition such as in traffic. Many words have multiple meanings, and so they likely prime, multiple categories of information. Even words that seem to have only a single category of meaning probably prime multiple categories of possible responses. For instance, when we read the word *sand*, more than one category of information might be facilitated. We might think of a beach. We might also think of activities, such as building a sand castle, the friends we were with, and emotions might be aroused as well. We might also think of an ocean or sea, and remember the smell of the air. Facilitation of examples of sand might also be facilitated, such as fine white sand, black volcanic sand, coarse sand, etc., according to an individual's experiences. All of these, then, would be associates of *sand*. Categories of information have been elicited by asking participants to write either the category items that compose a conceptual definition, examples of the category, or by providing the first word that occurred to the individual.

For instance, when Battig and Montague (1969) and Overschelde, Rawson, and Dunlosky (2004) presented the word *fruit*, and instructed their participants: "you will be given 30 sec. to write down in the notebook as many items included in that category as you can," participants produced examples of fruit. On the other hand, Kent and Rosanoff (1910) read to 1000 individuals the word *fruit*, as well as 99 other words, and asked them "to react by [saying] the first word which it makes him think of" (p. 3) and Nelson, McEvoy, and Schreiber (2004) also presented the word *fruit* as a cue in their free association study, asking participants to respond with the first word that occurred to them that was associated with that cue. In these free association studies, participants produced examples of fruit as well as *vegetable*, *cake*, and *sweet*, which are obviously not examples of *fruit*, but provides a wider view of what the word *fruit* meant to the individuals (see Table 1).

Free association studies provide associates from potentially all meanings of a word, while the category norming studies provide examples of the category. The Nelson, McEvoy, and Schreiber (2004) research provided an estimate of the mean semantic distances, the proportion of responses, for 72,176 words that were given in response to 5,019 cue words in their South Florida population of participants. In free association research, the responses are termed associates and the word that provokes the response is called the cue. The cue primes one or more associates, and the participant is often asked to respond with the first word that occurs to them. The cues and associates in the Nelson et al. study would be used in the research reported here to prime categories and measure priming.

Data from Nelson et al. and other free association studies have been used in priming research to prime and then to measure the priming effect (e.g., O'Neill, 1956; Yap, Tse, & Balota, 2009).

Table 1

Responses to the Cue Word fruit

Category norming studies		Free association studies	
Battig	Overschelde	K-R	Nelson
apple	apple	apple	apple
orange	orange	apples	orange
pear	banana	vegetable	vegetables
banana	grape	eat	banana
peach	pear	eating	cake
grape	peach	eatable	sweet
cherry	strawberry	peaches	cup
plum	kiwi	vegetables	eat
grapefruit	pineapple	trees	juice
lemon	watermelon	oranges	can

Note: The first 10 responses to the cue word *fruit* from:
Battig - Battig and Montague (1969),
Overschelde - Overschelde, Rawson, and Dunlosky (2004) ,
Kent - Kent and Rosanoff (1910), and
Nelson - Nelson, McEvoy, and Schreiber (2004)

(candidate constructed table from data reported by these researchers)

Factors Influencing Semantic and Category Priming

Along with association, other factors influence priming. Two major dimensions involved in memory access are conscious awareness and intentionality. In research, these dimensions are referred to by their extremes: liminal / subliminal and explicit / implicit.

In physiological research a different dimension is often used that seems to overlap these. Top-down and bottom-up systems initiating memory access refer to intentional cognitive control and stimulus control. Bottom-up is the more automated system, which would seem to encompass both subliminal and implicit priming situations. When this system (these systems?) initiate a search for meaning, frontal lobe controlled attention activity is not involved. These more physiological defined dimensions will be touched on as research is described, but most priming research seems to have been shaped by the psychological perspective, and so awareness and intentionality will be used to divide this section of the report.

Awareness

Researchers have used tachistoscopic presentations to study the influence of awareness on priming, and to isolate memory access from conscious control. In these studies, priming words are presented at very brief durations, too brief to be consciously perceived by participants (Fischler & Goodman, 1978; Greenwald, Draine, & Abrams, 1996; Hines, Czerwinski, Sawyer, & Dwyer, 1986; Perea & Gotor, 1997).

Priming studies have also often used lexical decision tasks to measure priming. Following the presentation of a priming word, a target word is presented which might be the priming word, a word that is related to the prime, a word unrelated to the prime, or just a collection of letters that at first glance might appear to be a word, might even be pronounceable, which is often referred to as a nonword. The participant is asked to make a word-nonword decision as quickly as possible without making errors, to measure the influence of the priming word on automatic processes, bottom-up processes. Research has found that word-nonword decisions to words related to the priming words have shorter response latencies than decisions made to unprimed words and meaningless letter strings. Subliminal priming studies have found that the priming word can be presented for a duration that is too brief for the word to be consciously recognized, but a priming effect occurs nonetheless, indicating that an automatic process had searched for meaning, as in the ambiguous word studies.

Fischler and Goodman (1978) reported two experiments that involved very brief stimulus onset asynchronies (SOAs), which is the term used for the time from priming word initial presentation to target word initial presentation. In their first experiment, priming words were presented at 550 and 90ms SOAs (which included a 50ms display of a random arrangement of lines before the target was presented), and the participant was asked to try to name the prime after making a lexical decision about a target word, which was either related or unrelated to the prime or was a nonword. Interestingly, the priming effect was not significant in a 90ms SOA when the participant was able to name the priming word, which occurred most often when the target word was related to the prime. Participants reported that attending to the prime word so that it could be named interfered with the lexical decision task; recognition of the word was occurring just at the time the lexical decision was to be made; these two processes competed. It seems as if intention was required for conscious awareness. Preoccupation with identification of the priming word conflicted with the process required for the LD decision.

To remove this co-occurrence, Fischler and Goodman removed a 50ms visual noise that had been displayed between the 40ms prime display and the LD, and naming of the priming word was “de-emphasized” in the instructions (p. 462). In Experiment 1, participants were able to name the prime in 48% of correct trials (trials in which the word-nonword decision was correct), while in Experiment 2, the prime was correctly named in less than 2% of the trials (most produced by two of the 12 participants), and the difference in LD RTs between related and unrelated targets was significant, $F(1,293) = 6.18$, MSe = 24,851, $p < .02$. It would have also been interesting to skip the LD and simply determine the number of participants who could identify the prime when it was presented at 40ms; note the average duration for identification in the Hines et al. study described next.

Hines, Czerwinski, Sawyer, and Dwyer (1986) also investigated priming effects at priming durations too brief for the priming words to be consciously recognized. They conducted an interesting experiment that added to information obtained by Swinney (1979), Kintsch and Mross (1985), and Till, Mross, and Kintsch (1988). Hines et al. investigated subliminal priming by first determining the minimum tachistoscopic time required for presentation of a word to be recognized, for each participant, and then displayed priming words just below that time, followed by QZQZQZQZQZ for 200 ms, followed by a target word, which the participant was to say (or *name* as research phrases it) the presented word aloud. The words presented were the first and fifth exemplars from the Battig and Montague (1969) category norms. In half the trials the first exemplar was the prime and the fifth exemplar was the target, and in the other half this was reversed. Results showed that subliminal presentations resulted in significant response latency facilitation only when the first exemplar was used as prime. The average presentation subliminal duration found was 41.6ms.

Greenwald, Draine, and Abrams (1996) reported a complex and interesting analysis from a group of studies in which subliminal priming declined when the prime duration was greater than 67ms. After 100ms, participants were aware of the priming word and facilitation increased again.

Participants in the study reported in Perea and Gotor (1997) also demonstrated significantly faster responding in a lexical decision (word-nonword) task to word targets that were related, compared to unrelated, to primes presented at 67 and 50ms, although priming was not found in a 33ms condition, $F(1,21) = 4.71$, $p < 0.05$), $F(1,21) = 19.07$, $p < 0.001$, $F(1,21) = p < 1.62$, respectively. Note that, in agreement with Greenwald et al., priming was greater at 50 than 67ms.

While it is probably true that all word identifications are the result of an automatic process, because we do not open our databases and consciously check item by item searching for meanings, the research conducted by Swinney and others demonstrated that an initial process that occurs when the meaning of an ambiguous word is being determined seems to involve an automated search of multiple categories of meaning that is automatically initiated. The research into subliminal priming I have summarized also indicates that this initiation is an automatic process, because Kintsch and Mross' sense activation stage occurs so quickly after an ambiguous word is encountered, before conscious intention and control could intervene. When reading, words seem to be initially analyzed outside of awareness sufficiently to identify the possible categories to which they belong, and that the selection of the appropriate category occurs following this is another automatic process, during the stage that Kintsch and Mross' labeled sense selection.

In addition to these automated processes that occur immediately following the presentation of a word, activities that occur immediately prior to these priming experiences appear to influence priming, in a priming that influences what will be primed. Kiefer and Martens (2010), found that a task that precedes subliminal priming can influence the obtained priming effect. In an EEG study, they found that when an unrelated preceding task requires attention to perceptual details, the priming effect of a subsequent semantic priming task was reduced compared to when the unrelated preceding task required attention to semantic characteristics. This finding will be related to results of cognitive style priming studies, summarized later here.

Intentionality

In some situations, at least, awareness and intentionality seem to run parallel to one another. All priming involves automatic processes. Even in explicit priming, preceding an intentional aspect of a response, associations are made out of awareness. Searching through stored memories looking for similarity or relatedness in the first instant when an identification is required/desired appears to be automated, as shown in studies involving ambiguous words when reading (Swinney, 1079). Research I have described shows that these searches and their initiation occur automatically and outside of consciousness.

There have been numerous studies that have used implicit priming and have apparently altered responses with this influence (e.g., Banaji, Hardin, & Rothman, 1993; Bargh, Chen, & Burrows, 1996; Epley & Gilovich, 1999; Kawakami, Dovidio, & Dijksterhuis, 2003; Kûhnen & Hannover, 2000; Lepore & Brown, 1997; Randolph-Seng & Nielsen, 2007; Shariff & Norenzayan, 2007; Srull & Wyer, 1979). In those studies, participants were asked to perform tasks that require awareness of the words and, to some degree, their meanings. In these tasks, the extent to which participants consider word meaning probably varied. For example, in some studies participants gave *liking* ratings to priming words as well as unrelated words, while in other studies the priming words were included in sentences that were scrambled and the participants had to unscramble them. In these studies, the semantic priming source was perceived consciously, and the participant had to give some attention to word meaning, but only as was needed to perform a task which they believed had a purpose other than to influence their subsequent memory access. They were not told that some subsequent activity, such as walking speed down a hall following what they were led to believe was the experiment, or the length of time it took them to interrupt a conversation between another person and the experimenter, or a following lexical decision task was going to be used to measure the effects of the initial task. Priming influence was provided without explicit intent of the participant. The automatic process of priming was initiated by an automatic process. Research to be discussed in the Priming Behavior section summarizes some of these studies.

Explicit priming has also been used. Free association studies such as Nelson et al. and the category norming studies made use of it. There have been studies focused on the investigation of the priming phenomenon itself that have utilized explicit techniques. For instance, the research reported in Landauer and Freedman (1968) also used explicit priming. They conducted their experiment on the effects of category size using explicit priming techniques, and Rosch (1975) reported a study in which an experimenter presented a category name to participants, and either simultaneously or immediately after, showed them two words and asked if both words belonged to the named category. They found that when both words were in the same category, responses were faster than when one word was and the other was not, demonstrating that priming of the explicitly provided category had occurred. This was explicit priming because participants expected words that might be related to the category presented, and so they would be expected to have intentionally primed that category.

Studies of false memories have also demonstrated category priming using explicit methods. Both Deese (1959) and Roediger and McDermott (1995) demonstrated how intentionally memorizing lists of associates of categories can lead to falsely remembering their category names as being included in the lists. Using cross-modal designs, both studies asked participants to remember auditorily presented lists of words which were associates of categories from the Kent and Rosanoff (1910) free association study, and on recognition testing, participants reported that some of the category names had been included in the lists. In the Roediger and McDermott (1995) study, participants also reported that they remembered hearing the category names among the "studied" words presented (p. 807).

Association Strength

This term refers to the likelihood that a concept will prime another concept. In research, it is also the likelihood that one word, a cue in free association studies, will produce another word. For example, in Table 1, *apple* was produced by 41 of the 184 participants, or 22.3%, in the Nelson et al. study as the first word that the cue *fruit* brought to mind. The proportion, 0.223, then, would be the efferent associative strength between *fruit* and *apple*. The reverse association; the likelihood that the word *fruit* would be produced by the cue *apple*, the afferent associative strength, was .154, meaning that *fruit* and *apple* are reciprocal associates. Research has found that the stronger the associative strength between two words the greater the priming power, and this is generally inversely related to recognition latency in LD tasks (e.g., Hines, Czerwinski, Sawyer, & Dwyer, 1986; Rosch, 1975). In the research here, the 10 associates with the greatest afferent strength with each category name, from the Nelson et al. free association study, were used as primes.

The associative strengths reported by free association and category norming studies between words for a group of individuals, estimated by the proportions of participants producing each response, might be considered as estimates of the associative strengths between the words for each individual of the group. Individual associative strengths between the words involved were expected to vary around these values. The words produced by the cue words reported by Nelson et al. do not include words produced by single individuals, so the most unusual associations were excluded.

Word Frequency

Scarborough, Cortese, and Scarborough (1977), Andrews (1992), Borowsky and Besner (1993), and Yap, Tse, and Balota (2009) found that words encountered frequently by individuals are recognized more quickly in LD tasks than words less frequently encountered. Scarborough et al. conducted their first experiment to test the hypothesis that when words are repeatedly primed and priming tested with a LD task, subsequent primings have reduced impact on facilitation. RT decreased on the second presentation, less for high frequency words, as expected. However, on the second presentation, they were the approximately the same, suggesting that word frequency is the likelihood of a recency effect, or frequency could be considered recently and repeated priming by common experience.

Stanovich and West (1983) later found that access to difficult words were facilitated more than access to easier words, although word difficulty was defined in terms of word frequency and word length. Scarborough et al. also reported that research has found that frequency is correlated with both the number of meanings and the age at which a word is generally learned, so word frequency might be a measure of several factors that produce shorter RTs in priming research.

Borowsky and Besner (1993) also found that word frequency lowered LD RTs, in the third experiment they reported in that article. The goal of their research was to determine if word context, stimulus quality, and word frequency interacted or produced additive effects on word identification (“processing” p. 813). Additive effects would indicate that their influences were on different stages of word identification, and interactions would indicate that their influences were on the same stage(s). Their third experiment involved two conditions for stimulus quality (intact and degraded), context (related, unrelated, nonword), and frequency as a continuous between-participant variable (Word frequency is highly skewed. They used (40 + log10 (frequency + 1)) to correct this.). Word length was a constant at five letters. Stimulus quality is an interesting variable. Either the participant had trouble reading a degraded display of the words or the words were displayed clearly. The context-frequency analysis was conducted with the two stimulus quality conditions collapsed, and also with RTs from only the degraded stimulus quality condition, leaving this reader wondering what the analysis with intact word quality would have shown.

> In assessing the joint effects of Context and Word Frequency in a design as complex as the present one there is a choice to be made in terms of whether to collapse across the Stimulus Quality variable or to analyze at the level of Stimulus Quality that elicits the largest effects of Context and Word Frequency. (Borowsky & Besner, 1993, p. 828)

They reported that the degraded condition produced the greatest effects. In both the collapsed and degraded stimulus quality analyses, word frequency had a significant impact on RT: $F(1, 159) = 10.51, p < .001$, $MSe = 8{,}085$ and $F(1, 159) = 6.30$, $p < .05$, *MSe* = 30,149, respectively. Context, not unexpectedly, produced significant results in all analyses.

The researchers also reported that the word length in their second experiment "was substantially correlated with word frequency" (Note, pp. 826-827), but the correlation was not reported. In their experiment 3, Kucera and Francis (1967) norms were used, so an assumption is being made here that those were the frequencies that the word lengths in their first two experiments were correlated with. The correlation found by this candidate between the word frequencies from Kucera and Francis, provided by Nelson, McEvoy, and Schreiber (2004), for 218 of the priming words from Borowsky and Besner's Experiments 1 and 2 was -0.264, a correlation of -0.134 was found between the two variables for the target words, and a correlation of -0.211 for the combined 437 prime and target words. In the Nelson et al. data, the correlation between the 4678 frequencies they provide and Cue word length is -0.148.

In their discussion they concluded "Context aids low-frequency words more than high-frequency ones. Although this interaction was only marginal in Analysis 2 (p = .12 collapsed across Stimulus Quality; p = .10 under the degraded condition)." So there was some relationship, but it was not significant, small and not reliable. These results could have been obtained by chance 10-12% of the time. They continue, "the previous findings of an interaction between Context and Word Frequency by both Becker and McDonald (1980) justify raising our alpha level to .10" (p. 831).

Priming and word frequency do not seem to interact in all participants, though. Yap, Tse, and Balota (2009), with a complex analysis, promoting the use of measures other than the mean so that distribution shift and skew can be analyzed, compared high and low vocabulary participants and word frequency on LD performance, and found that priming effect and word frequency interacted in low but not high vocabulary participants.

Neighborhood Size

Neighborhood size refers to the number of words that are lexically similar to a word, and this size is determined by changing single letters to create other valid words, "For example, the word GAME has the neighbors *came, dame, fame, lame, name, same, tame*, *gale*, *gape*, *gate*, and *gave* and therefore a neighborhood size of 10" (Andrews, 1989, p. 805). In their first experiment, a main effect for neighborhood size was significant in only the analysis of error rates, and high frequency words produced shorter LD RTs. There was also an interaction between neighborhood size and frequency, with low frequency, large neighborhood size producing the shortest RTs, contrary to this reader's expectation that large neighborhood size would create and initial confusion, lengthening RTs in all cases. Presumably a perceptual priming effect was involved. Andrews found that LD response latencies to low frequency words were facilitated by neighborhood size; the larger the neighborhood, the faster the access to low frequency words. This interaction is a factor to be considered when utilizing the LD task in order to take into account its influence on facilitation, although words with fewer letters might be the main source of the influence. No research has been located that has measured the impact of this interaction in LD tasks following semantic / category priming.

Category / Set Size

Similar to neighborhood size, but with an opposite effect, category size might need to be considered when choosing categories for a study such as the one reported here. Landauer and Freedman (1968) found that category membership decisions are effected by category size. Specifically, using nested categories (word, noun; names of living things, animals, dogs) they found, in their first reported experiment, that decisions that an object was not a member of a large category took longer (53ms) than decisions that an object was a member of a smaller category, $t(23) = 3.66$, $p < .01$. Their second experiment used 17 nested categories: adjective – color, food – vegetable, vehicle – car, profession – type of clergy, country – European country, city – U.S. city, title – military title, element – metal, building – place of worship, beverage – alcoholic beverage, clothing – footwear, musical instrument – stringed instrument, stone – gem, animal – dog, plant – flower, 1-5 – 1-2, first name – boy's name. Participants made category membership decisions for 10 items per category. The priming was explicitly given by the experimenter who spoke the name of the larger or smaller category. Each participant sat with eyes closed, and a finger on a switch, that, when removed, started the timer. A list of 10 items was placed in front of the participant, they opened their eyes and released the switch to start the timer, placed check marks next to items included in the category, then stopped the timer and closed their eyes waiting for the next list and category. Even with this early-technology method, the difference between category decisions for larger categories took significantly longer, $t(47) = 3.39$, $p < .01$, with 48 Stanford undergraduates, suggesting, as Anderson (1974) would later, that the category membership searches were serial, at least in intentional searches.

Rips, Shoben, and Smith (1973) used category classification response times and found that, generally, the more closely related an instance was to a category (“A robin is a bird” vs. “A robin is an animal”) the less time was required to make the classification decision of correct vs. incorrect. Although the focus in the study was semantic or associative distance, these results could also be viewed from a category size perspective. Classifying an example in the category *animal* might mean that more possibilities had to be checked to test the proposition, than classifying the example in, for instance *bird*. This would be seem to be an indication that each concept does not contain categorizing information, contrary to what the compound cue model might predict.

Similarly, Anderson (1974) taught participants proposition such as “A hippie is in the park. A hippie is in the church. A policeman is in the park. A sailor is in the park” (p. 452), with a varying number of facts about people being in locations, which constituted varying category sizes, and found that participants took longer to make a true/false decision when more facts about the object had been memorized, and false decisions took longer than true ones. While these findings do not at all seem surprising, they do demonstrate that, as Anderson pointed out, a serial search must be occurring rather than a parallel search. If a serial search is conducted, then a false response could not be given until every related proposition was checked, sequentially one by one, whereas a true response could be produced, most of the time, without checking every proposition. A parallel search might be expected to take the same times for searches of any category size, within an individual's category priming capacity limitation. While these categories were not the overlearned ones used in the Rips et al. study, it is indication that all categorical information is not stored with every concept. Considered with the results summarized in the Resolving Ambiguity and Hemispherical Laterality sections that seems to indicate that intentional searches are serial and carried out in the left hemisphere, while automatic searches are parallel and carried out in the right. So, in the case of serial, conscious, intentional searches; the larger the category, the longer the RT.

No research has been located to provide similar information concerning parallel reflexively initiated searches. Research replicating Andrews' (1989) finding that "responses to low-frequency words from large neighborhoods were faster" (p. 237) has not been located. That finding seems to mean that searches that narrow the alternatives based on perceptual priming are faster, but it might not provide evidence for the effect of semantic category size in parallel searches.

Number of Priming Experiences and Duration of Priming Effects

Along with the other influences listed here, semantic and category priming have been found to be influenced by the number of priming experiences and depth of engagement of the priming task. Research into semantic priming using single brief presentations has found that priming disappeared after a few intervening words, or a single one. Interestingly, this line of research followed research that found lasting category priming using multiple presentations. Studies have clearly demonstrated that category priming with multiple priming of the same category can last for at least 24hrs. Of course there is no guarantee that semantic and category priming are interchangeable in these studies.

For example, Balota and Lorch (1986) found that after one unrelated intervening word, semantic priming effect was not significant in their LD experiment, but that facilitation was measurable when the task was naming the target word. Masson, (1995), which described a distributed memory model of semantic priming, reported results that showed that semantic priming might have very brief effects, or be disrupted by intervening meanings that become the focus of attention. His data did also show facilitation, although it was reduced, in the unrelated intervening word condition, not an absence of facilitation. Joordens and Besner (1992) also demonstrated a reduced, but clear, facilitation with a single intervening unrelated word.

Using and implicit task, Srull and Wyer (1979) compared differences in implicit category priming facilitation, using a task similar to that utilized in the reported research, with varied numbers of priming experiences and three conditions of varied SOA durations, measuring the effects immediately following the priming experiences, 1hr later, and 24hrs later. The number of priming items in the priming task and the percentage of priming items (priming plus filler) in each priming *questionnaire* was also varied (20% (5 or 12 priming items) and 80% (24 and 48 priming items) of 30 or 60 total items, respectively. To hide the purpose of the priming experience, participants were stopped by an experimenter confederate on the way to what they believed was the study they expected to participate in, and asked to complete a questionnaire for another study. In the *actual* study that followed, they judged the character of a person in an ambiguous vignette on dimensions of hostile, unfriendly, dislikable, kind, considerate, and thoughtful…boring, selfish, narrow-minded, dependable, interesting, and intelligent. Ratings on the dimensions before the ellipsis measured priming, the rest were fillers. Results showed that in the immediate and in both delay conditions priming effects were evident, lessening with SOA, and increasing with the number of priming experiences.

Graf, Shimamura, and Squire (1985) also demonstrated lasting priming. These researchers primed three categories by having participants make *liking* decisions to words and then tested priming by eliciting eight examples from each category when the category label was provided, which had not been included in the priming task.

Ray and Bly (2007) conducted a study in which priming was measurable for each of three category names in a task in which lists of 10 words associated with a category name, presented sequentially in a block format, primed the categories, so 20 words intervened between the priming of the first category and its testing.

Affective priming studies to be described, have also found lasting priming effects.

Linear Increases. So, research has shown that multiple category priming experiences produce relatively lasting effects. Although it seems likely that the top of the relationship would have an asymptotic form, research has found that increases are additive in the lower end of the range. That is, two experiences have roughly double the effect of one. For example, in a study comparing priming between normal controls, and Broca's and Wernicke's aphasia patients, Milberg, Blumstein, Giovanello, and Misiurski (2003) found additivity when two priming experiences were presented to the control group. They used word triplets in which the first or second word was related to third word that was used as a LD target, or both or neither was related, using nonwords in the unrelated conditions.

Interestingly, Tsai, Wu, Hung, and Tzeng (2007) investigated the difference in priming effects between homonymous, polysemous, and monosense words, and found that for homonyms, both homonymous and polysemous, priming was additive, while for monosense words, priming effect was underadditive, suggesting that when priming separate meanings, each is primed, and multiply priming the same meaning decreases RT, but by a different pattern.

Borowsky and Besner (1993) found that stimulus quality and context produced an interactive effect, indicating that they influenced the same stage of word identification, stimulus quality and word frequency did not interact, and context and word frequency showed a "marginal" interaction: $F(l, 102) = 2.73$, $p = .10$, $MSe = 22{,}142$ (p. 830). Could the effects of word frequency, though, influence both the same stage as context and a separate stage, producing the "marginal" interaction? The researchers did not consider this in the article and concluded that the influences are on separate stages.

In an fMRI study, Whitney, Grossman, and Kircher (2009) presented "word-triplets," such as wine–seed–grape, to participants who were to decide if the last word was related to at least one of the preceding words. They found a linear activation increase in an area of the left prefrontal cortex when both preceding words were related to the last one over the increase found when only word was related.

Priming Social Perception, Affect, and Cognitive Responses

The first two of the priming targets covered here in at least some cases probably involve the priming of emotion. In addition, some psychological disorders, such as post-traumatic stress syndrome, might involve both affective and cognitive priming. The last category, the priming of cognitive responses, might be the most important for education, but understanding it might also provide a better understanding of affective priming and priming that influences social interaction.

Priming Social Perception

Although attitudes occur in domains other than the social one, research seems to have focused on attitudes as they are involved in social perception, so these are considered in this section.

Kûhnen and Hannover (2000) used interdependent and independent self-knowledge to prime judgment of similarity between self and other. Corcoran, Hundhammer, and Mussweiler (2009) primed a tendency to look for differences which resulted in participants sitting closer to a "skinhead" (p. 1009) seated in a waiting room, and in their second experiment, they used the same procedural technique and found that priming attention to differences decreased gender stereotyping, using a role-playing format in which the participant had to decide if a male or female employee “was qualified for an IT-training program” (p. 1030). While the male employee in the role-playing was judged with approximately the same stereotyping in both the similarity and difference priming conditions, more stereotyped female characteristics were used to describe the female employee in the difference but not the similarity condition. Although there were both male and female participants (the numbers were not reported), a by-gender analysis was not reported.

Casper, Rothermund, and Wentura (2010) used multiple primes in their research of priming effects on stereotyping. Stereotypes were primed by presenting an image and a word that was either stereotypically congruent with the image or not, and then a word appeared on the same screen for which the participant was to make a lexical decision response. They found that when there was congruence, lexical decision responses were faster (e.g., the target word *beer* with a beer house scene with the LD word *Bavarian,* or the target word *clumsy*, with an image a poorly parked car and the LD word *woman*), indicating that priming of a stereotypical category was greater when information was congruent.

Kawakami, Dovidio, and Dijksterhuis (2008) also investigated the influence of priming on stereotypical attitudes. In their first experiment, participants either described an elderly or young woman from a picture provided. Following this, in a supposedly unrelated task, they rated attitudes in a questionnaire as similar or dissimilar from their own attitude. They were not told that the attitudes in the questionnaire were typically held by the elderly, as shown in a pilot study. Those participants who described the elderly person rated more of the elderly attitudes as similar to their own, $F(1, 35) = 4.57$, $p < .05$.

Priming Emotion: Affective Priming

Lyttle, Dorahy, Hanna, and Huntjens (2010) compared priming in PTSD patients with non-PTSD patients. They reported that PTSD symptoms appear to be the result of bottom-up rather than top-down processing, with environmental stimuli priming traumatic memories. Top-down (cognitively controlled) and bottom-up (environmental/stimuli controlled) processes seem to have an inverse relationship; as top-down controlled processing increases, bottom-up automatic processing decreases, and vice versa. As a result of this, priming can be an influence on bottom-up processing, a priming difference might be found between PTSD patients and controls. Because these memories are so intense in PTSD patients, top-down controlling processes are inhibited. These researchers compared perceptual and conceptual priming of trauma related words in 25 PTSD patients (17 male), and compared their performance to 25 other mental health patients (also 17 male) who had also been traumatized, but did not meet the criteria for PTSD diagnosis. The research involved individuals who had experienced trauma in the Northern Ireland' "Troubles" (htm version, no page number). The two groups were compared on a variety of clinical measures as well as on their conceptual and perceptual priming performance. Priming words included Troubles-related words, general threat (non-Troubles-related), and neutral words. The experimental procedure involved an encoding phase, followed by a 15 minute distraction task, followed by the conceptual and perceptual priming measurement tasks. The conceptual priming measure was the generation of words to the different categories of priming words, and the perceptual priming measure was a word-stem completion task. As predicted, the PTSD group's perceptual priming was greater than their conceptual priming, and the opposite was true for the comparison group.

There has also been some interesting research investigating the priming of emotional valence. For example, Fazio, Sanbonmatsu, Powell, and Kardes (1986) demonstrated that an object associated with a positive or negative attitude could facilitate valence decisions for adjectives of similar valence, and inhibit responses for opposite valence adjectives. The investigators reported that their previous research had determined that "latency of response to an attitudinal inquiry appears to index the strength of an object-evaluation association satisfactorily". Making use of this relationship in the study described, 70 words, "including the names of some individuals, animals, foods, social groups, nations, activities, and physical objects" (p. 331) were presented, one at a time, to each of 22 undergraduate participants, who made a "good" or "bad" decisions to each as quickly as they could without making errors by pressing a key on a computer keyboard. Their RTs, then, could be used as an estimate of affective associative strength. From the 70 words, two strong positive, two weak positive, two strong negative, and two weak negative associates were selected to be used as affective primes. In each trial, one of these primes, or a neutral letter-string (e.g., “BBB”), was presented to participants for 200ms, followed by a 100ms blank screen, followed by one of 10 positive or one of 10 negative adjective (e.g., “appealing,” “delightful,” or “repulsive,” “awful”). Participants were to press a key to indicate as quickly as possible without making mistakes whether the word was “good” or “bad”. Results showed that RTs for the adjective valence decision was significantly related to priming condition (strong positive, weak positive, strong negative, weak negative, neutral), demonstrating that emotional responses, emotional valence decisions, were susceptible to priming influence.

Bargh, Chaiken, Govender, and Pratto (1992) replicated this finding, and extended it to attitudes that were not at the valence extremes. More recently, Eder, Leuthold, Rothermund, and Schweinberger (2011), in an EEG study, found that both pre-motor and motor “lateralized readiness potential“ (p. 2) indicators predicted response latencies, in their regression analysis, in an affective decision task, primed by a simultaneously displayed image, which indicated that both semantic and procedural (motor), both preparation and response stages, might be influenced by affective priming. Their results might also be evidence that semantic and premotor preparatory responses are a part of the full concepts that were activated by the priming image.

Priming Cognitive Skills, Styles, and Information

While priming attitudes in preparation for lessons in education might be a useful strategy, the priming of cognitive styles, goals, and cognitive access to information would likely be at least as important.

Recall that Kiefer and Martens (2010) found that when a preceding task required attention to perceptual details, subsequent priming on a semantic task was reduced compared to when attention to semantic details was required by a preceding task. Similarly, the research reported in Kûhnen, Hannover, and Schubert (2001) had theorized that independent and interdependent self-construal involve both semantic and procedural components. In the first experiment they reported, they used interdependent and independent self-knowledge to prime performance on the Embedded Figures Test (EFT). To prime an independent style, participants were asked to think about differences between themselves and their family and friends, and to prime interdependence, they were asked to think about how they were similar. As expected, the independent primed group outperformed the interdependent group on the EFT, $F(1,47) = 5.14$, $p < .05$. They conducted a similar second experiment to determine if thinking of differences, in and of itself, improved performance on the EFT, or, was the independent self-construal, as their Semantic-Procedural Interface model of the self (SPI) predicted, the cause. The second study was conducted with 191 participants, and the two self-construal conditions were created by the same method as in the first experiment. In two additional conditions, participants were asked to think about differences or similarities between cats and dogs, and a no-prime condition was also added. Their result replicated those of the first experiment, participants in the independent priming condition scored higher on a group version of the EFT, $t(186) = 2.11$, $p = .02$, however, participants who thought about differences between cats and dogs did not outperform participants who thought about their similarities. The authors interpreted this as evidence for their SPI model, but it also seems possible that the more personal comparisons engaged the differences and similarities processes more than the less personal ones, producing a greater priming effect. This is not to say that the semantic and procedural model seems incorrect, only that the inclusion of the self might not be necessary, only the extent of engagement of a task. One way to test this would involve the use of an fMRI, because the posterior cingulate cortex has been found to be a center for personal conceptions (e.g., Johnson, Baxter, Wilder, Pipe, Heiserman, & Prigatano, 2002; Shah, Marshall, & Zafiris, 2001).

Kûhnen and Oyserman (2002) primed cognitive style by having participants circle pronouns in a passage that either referred to their self (“I,” “me,” “mine”) or themselves and others (“we,” “our,” “us,” p. 494), priming independent or interdependent self-knowledge. Cognitive style was then tested using a gestalt-like letter identification task in which a large letter was composed of smaller letters that were different. Participants in the independent group tended to choose the smaller letters, $t(14) = 2.01$, $p = .03$. However, the participants interdependently primed did not more often choose the larger letter $t(14) = -.83$, $p = .21$. In their second reported experiment, interdependently primed participants were significantly more able to identify what they had seen in a drawing of a variety of small scattered objects and where they had seen the objects, than independently primed participants, demonstrating that priming interdependence primed a more context-aware style ($t(32) = -2{:}0$, $p = .03$).

Replicating and extending findings of an earlier study, Lemaire, Barrett, Fayol, and Abdi (1994) found that solutions to arithmetic problems were primed by presenting participants with addends. Similarly, Was, Paternite, and Wooley (2008) primed access to arithmetic facts in their research. Number families were defined as a group of simple equations that result in the same solution, for instance all the simple equations that solve to the number six. These families were believed to be stored in an interconnected network in long term memory by the researchers. Priming the family by presenting some of the equations should then prime the entire family, or category. For example, seeing the unsolved equations 2 x 3 and 12 / 2 should prime 30 / 5. Each trial in their experiment consisted of four parts and involved three number families, focused, ignored, and unrelated. First participants were shown four simple arithmetic equations from these families, one at a time, and asked to remember the answers to two of them, "*Remember the answer to the equations 3 x 3, 45 / 5*" (p. 1482), that was their focused family. When the instructions to ignore were presented is unclear in the report. Following these presentations and the instruction, participants were shown eight two-equation presentations, and asked if the answers were the same or different from one another, which they indicated by pressing either the "L" for "Like" and "D" for "Different". These eight equation pairs were either from the focused, ignored, and an unprimed number family. This sequence began by priming the response behaviors with two "warm-up" (p. 1482) equation comparisons with answers that were unrelated to the families the participant was asked to remember or ignore. Results showed that reaction time to equation comparisons for both ignored and focused families were faster than comparisons for unprimed families. Interestingly, ignored family comparisons were the faster than focused family comparisons, although this difference was not significant, (F (1, 52) = 1.66, MSe = 67040.53, partial $\eta 2$ = .03, p > .05).

Capacity in Priming Categories

As reported here, no research has been located which has investigated the capacity of priming semantic categories in individuals. Moreover, no research has been located which has even discussed the capacity. Yet, because no capacity in the brain is likely to be limitless, this capacity must have a mean and a range of values in the population. A reasonable guestimate might be that the value is in the range of immediate memory capacity, and categories are accessed as chunks, but there are indications that this is not the case.

For example, Rips, Shoben, and Smith (1973) used category classification response times and found that, generally, the more closely related an instance was to a category ("A robin is a bird" vs. "A robin is an animal") the less time was required to make the correct vs. incorrect classification decision. Interestingly, and the point here, is that they found that "A bird is an animal," "A mammal is an animal," and "A car is a vehicle," which involve decisions about relatively superordinate categories, rather than an item and a category, such as "A robin is a bird," or "A Dodge is a car," produced response times that were so long that they were excluded from analysis. The researchers provided the cause of the long RTs as, "Since subjects did not expect to see words frequently used as predicate nouns in the subject position" (p. 6), but it seems possible that the long response times could have been the result of several different causes. For example, they might have reflected the difficulty in priming, or differentiating the priming, of a category within category, and the effort leaves insufficient system resources available for further analysis. It could also reflect different processes in the left and right hemispheres (see Shears & Chiarello (2003. p. 4, for a discussion).

Neither of these speculations changes the probability that simultaneous categorical priming likely has a limited capacity, and that there is likely a mean and range in the population which has yet to be empirically measured. But it is also possible that Rips, Shoben, and Smith's findings indicate that the reported research could have found that the number was one, and a recency or primacy effect might be all that was found.

As was noted earlier, research has focused on priming single categories. For example, Bousfield and Sedgewick (1944) studied the course of free association responses. Participants were given a topic, for instance "quadruped animals," and were asked to write down every example they could think of. In general, responses followed a curve described by a function, and so the changing rate of production was predictable. Within the overall response curve there appeared to be instances of smaller versions of the curve, as brief bursts of responses occurred when participants refreshed their sets of available responses with subcategories of the main theme, such as domesticated quadrupeds and jungle quadrupeds, for example. While that research specifically targeted single broad categories, primed by the request to name examples, the sequential brief bursts could indicate that priming a broad category also primes its subcategories, which participants focused on serially, with the bursts marking the release from inhibition as each new category becomes the focus (Wixted & Rohrer, 1993).

Research has also primed religious attitude, politeness, aggressive behavior, bias in the interpretation of ambiguous vignettes, cognitive style, behavioral categories (e.g., elderly behavior), as well as other cognitive sets (Banaji, Hardin, & Rothman, 1993; Bargh, Chen, & Burrows, 1996; Fazio, Sanbonmatsu, Powell, & Kardes, 1986; Kûhnen & Hannover, 2000; Kûhnen, Hannover, & Schubert, 2001; Randolph-Seng & Nielsen, 2007 ; Srull & Wyer, 1979). This line of research demonstrated that many different types of psychological sets of information can be primed. It provided evidence that influences such as movies, videos, advertising, and games can prepare or bias responses in daily activities, but none of the studies attempted to prime more than one category of responses during an experimental session.

However, there is also evidence that the priming of more than a single category can be maintained for a time. Graf, Shimamura, and Squire's (1985) primed three categories of information in their second experiment by having participants make *liking* ratings to words read to them, and then measured the priming with free recall and category-exemplar listing tasks. In the free-recall condition, participants were asked to list as many of the words that they could from the *liking* task, the priming task, while in the category-exemplar listing task they were simply asked to list examples of categories provided by the researcher, without reference to the words to which they had given *liking* ratings. Priming of the three categories was demonstrated in the amnesia group in the category-exemplar listing task but not in the free-recall task.

Ray and Bly (2007) also demonstrated multiple category priming by having participants make liking-ratings on items (words) from six categories, three priming and three filler, and a fairly large effect size was found with only 12 participants. They then had participants make LDs (word-nonword) on both primed words, other examples from the same three primed categories, and unrelated words and found facilitation in both primed and unprimed words from the three primed categories. This was a solid demonstration that multiple categories had been simultaneously primed. In both Graf, Shimamura, and Squire’s (1985) and Ray and Bly, an implicit priming procedure was used. Participants were not asked to remember the priming words or note categories to which they belonged, which would have brought intentional memorization into the study and changed the interpretation of the results.

In their second experiment, Hines, Czerwinski, Sawyer, and Dwyer (1986) displayed images for very brief durations, hovering around a subliminal exposure, which was determined separately for each participant, and then each participant was required to name the item in the image. The images were items from categories from the Battig and Montague (1969) category norms, and the primes were each from a different category. The researchers then re-presented the images at the subliminal durations and required participants to name the image. The group was then divided into high and low success rates, and researchers found, strangely, that the two groups did not significantly differ in their semantic priming performance. The interesting result reported was that the average participant was correct in 23% of the forced choice naming attempts, the low group having a mean of 13% and the high group 33%. It is possible that these numbers could indicate each individual's category priming capacity, or be related to it. This would suggest that the mean that the reported research would find would be in the range of two to three. One confounding influence was that the participants were told that they would be seeing images that had been presented earlier, and this could have caused influence from episodic memory. Episodic memory stores information about personal events rather than simply facts, and by asking participants to recall "pictures viewed earlier" (p. 373), recall success might be enhanced by this (see Baddeley, 2002; Tulving & Thomson, 1973, p. 354, for a brief description of episodic memory). No studies have been located that have investigated episodic recall to subliminal presentations.

In addition to these examples of priming multiple categories are the studies of ambiguity reported by Swinney (1979), Kintsch and Mross (1985), and Till, Mross, and Kintsch (1988). Recall that in those studies, initially, categories other than that relevant to the context of the sentence were also primed, although there was no way to measure the number of categories primed.

Scrambled Sentences/Phrases as a Priming Technique

As reported here, access to many different types of categories of psychological information have been primed in previous research. Many of these studies have extended the brief priming duration found in tachistoscopic studies by providing multiple priming experiences for a single category, using an implicit scrambled sentence task.

Unscrambling sentences focuses attention on the meanings of the individual words and the overall meaning of the sentence, providing a context and a single meaning for ambiguous words. The words must be identified in long term memory in order for their meaning to be comprehended in order for a meaningful sentence to be constructed, but there is no requirement for intentional memorizing of the priming words or their meanings.

In 1955, Watson, Pritzker, and Madison described a test of hostility in which an individual was asked to make a three-word sentence from four presented words. In an interesting turn-about, modifications of this technique have been successfully used to prime rather than measure hostility. Srull and Wyer (1979), described earlier, seem to have been the first researchers to prime with scrambled sentences. Their research successfully primed one category at a time: -. Other researchers then began using the task successfully.

Banaji, Hardin, and Rothman (1993) primed stereotyping with scrambled sentences, with 81 participants in their first study (46 women and 35 men) which primed dependence. Participants rated men and women in vignettes on this and a few other traits. In their second experiment, aggressive responses were primed in 141 (72 women and 69 men) participants. Results showed that females in the ambiguous vignettes were rated as more dependent by those primed with dependence, and men were rated as more aggressive by participants primed with aggression.

Bargh, Chen, and Burrows (1996) used scrambled sentences to prime politeness and rudeness, measured by the length of time before they interrupted the experimenter who was supposedly engaged in a conversation in the hallway, and an elderly mindset, measured by walking speed to an elevator, supposedly after the experiment had been completed. Kûhnen and Hannover (2000) investigated self-construal that resulted from priming with scrambled sentences, measuring the effect of the priming with a questionnaire that asked the participant to describe their similarity to someone they knew, but someone who was not a close friend. Participants in the interdependent condition rated themselves as more similar. Randolph-Seng and Nielsen (2007) used scrambled sentences to prime, they said, honesty, by including words that have religious connotations. Participants primed with the religious sentences cheated less in a task of drawing circles with their eyes-closed, while alone in a room. Shariff and Norenzayan (2007) also primed religious honesty or religious or moral attitudes. They used five priming sentences and five filler sentences with 50 participants, and then they played a game in which cheating would be easy and no one would know. Participants primed with religious scrambled sentences such as, “felt she eradicate spirit the,” and “the dessert was divine” allocated more money to another person in a game in which they were an anonymous partner.

Summary and Conclusions

Research has shown that cognitive, affective, and attitudinal information is primed by prior exposure to similar information, and that multiple exposures to priming experiences increases the duration of the priming. Although research has not yet determined the maximum number of categories, and the mean and range of this value in the general population, it has shown that three categories of information can be primed, and that the priming is measurable after three other categories are primed. Neither Ray and Bly (2007) nor Hines, Czerwinski, Sawyer, and Dwyer (1986) investigated category priming capacity, but their results did appear to demonstrate facilitation of three categories. In addition, studies have conclusively demonstrated that single categories, in the form of behaviors and attitudes, can be primed (Banaji, Hardin, & Rothman, 1993; Bargh, Chen, & Burrows, 1996; Fazio, Sanbonmatsu, Powell, & Kardes, 1986; Kûhnen & Hannover, 2000; Kûhnen, Hannover, & Schubert, 2001; Randolph-Seng & Nielsen, 2007 ; Srull & Wyer, 1979). The reported research used a similar task, except that the task required three-word phrases, instead of sentences, to be unscrambled, and attempted to prime five categories before measuring the priming, attempting to identify the mean and range of this capacity in the group of participants who volunteer. Specifics of this and the data gathering plan, as well as the analysis of the data recorded from the scrambled phrase and lexical decision tasks follows. Chapter III will report the research Methods that were used in the research I conducted.

Chapter III: Research Method

Introduction

I attempted to measure the category priming capacities in a group of 20 participants. Five categories of information were primed, using a scrambled phrase task, and the number successfully primed in each participant was be measured using a lexical decision task. This provided the mean and range of category priming capacity within the group, the main result sought by this research. This research was been approved by Walden University (IRB#: 05-29-13-0090128).

This chapter will describe the methods and materials used in the research reported here, as well as justify the choices made citing past research. Presented first in this chapter will be a description of the research design and approach, followed by the reasoning and evidence that produced the sample size, along with a description of the population from which it was drawn, and the characteristics that were required in participants. Next, the Instrumentation and Materials section will describe the presentation pages used to collect data, how the categories, words, and nonwords were selected, and from where they were obtained. This will be followed by specifics of the data collection procedures and a description of the analysis. Finally, a description of security measures used to protect participant data will be provided, and the impact that the treatments in the research conducted might have had on participants will be considered.

Implicit, unintentional priming is the focus of the research. That is, priming that is intended by the researcher, but not by the participant. This is an influence on behavior and perspectives that is not explicitly recognized or intentionally considered by individuals, and yet, as research summarized in Chapter II has shown, it can have a strong influence on responses in social interactions as well as attitudes toward phenomena encountered.

Research Design and Approach

The research reported here was quantitative and quasi-experimental. A scrambled phrase task primed five categories of information, and a lexical decision (LD) task measured that priming (The tasks are described in the Instrumentation and Materials section). Participants made word-nonword decisions to the words related to the primed categories, to words unrelated to them, and to nonwords in the LD task. The time it took to make a decision was the response latency (RL). The mean RL of the lexical decision responses to the unrelated words was the control measure, the baseline, to which the related words RL means were compared.

Relatedness of the words in the LD task was the independent variable manipulated. LD words were either be related or unrelated to the primed categories, or they were nonwords. LD RL is the dependent variable. As shown in Chapter II, past research has found that LD RLs have been found to be significantly shorter for words associated with primed categories than for those of unrelated words.

A one-way ANOVA was used to compare the variance between the LD RLs of the five primed categories to that of the unprimed words. The number of significant differences found in the grouped data provided the most useful finding.

The research design also provided for an attempted partial replication for Ray and Bly's (2007) finding that more than a single category can be primed and the priming can be maintained during the priming of other categories. Their research seemed to demonstrate that category priming capacity has an upper limit of at least three. The priming of five categories was attempted in the present research, because attempting to prime more than five might possibly make the scrambled phrase task too lengthy, and participant attrition might become a problem (see Instrument and Materials section / Selection of Categories and Related Words / Selection Process).

Initially, a particular type of noun, place labels, was chosen, simply by separating the nouns among the cue words in the Nelson, McEvoy, and Schreiber (2007) database, to try to locate categories that had some commonality. I selected ten categories by first creating a spreadsheet that contained nouns that represented place labels, such as hospital, school, etc. This group of words was sorted by total number of efferent associates, and, because 10 efferent associates would be needed in the LD task, the first 10 efferents from each of the potential categories was processed by an Excel macro developed to report the number of interrelationships between associates. Those with the smallest number of interrelationships would be the most unrelated. Inspection of these associates showed that the mean associative strength was very low, and so the process was used again on all nouns. Again, 10 were selected that had more than 10 efferent associates, and the ten with the highest efferent associative strength were chosen. This produced a list of 10 nouns: *baby*, *clothes*, *boat*, *car*, *doctor*, *television*, *fruit*, *bread*, *hair*, and *school*. Following this, it was decided that using 100 scrambled phrases in the priming task (10 phrases for each category) might be too taxing on participants and attrition might be too high. It was also believed that, based on research (Hines, Czerwinski, Sawyer, & Dwyer, 1986; Graf, Shimamura, & Squire, 1985; Ray & Bly, 2007) and personal experience, that implicit priming capacity was not be likely to be greater than six, so the mean associative strength of the efferents were compared. Because they were fairly similar, the mean associative strengths of the afferents were also considered. Five categories were found to be particularly similar, so these were selected *television*, *bread*, *hair*, *fruit*, and *school* (see Appendix A).

The mean associative strength of the words used to prime a category in the scrambled phrase task reflected the amount of priming expected to be produced for each category, because, as reported in Chapter II here, frequency has been found by previous researchers to be positively associated with priming effect (e.g., Graf, Shimamura, & Squire, 1985). Therefore, similar mean associative strengths increased the likelihood that they were primed equally, potentially producing the greatest number of primed categories. The phrases that were unscrambled defined the context of the priming word meaning. A few that were difficult to create scrambled phrases clearly designating the category were replaced with other afferents of lower associative strength.

Comparing related and unrelated RL from the LD task has been an accepted means of measuring priming in past research. For example, as described in Chapter II, Stanovich and West (1983) investigated the influence of word difficulty on priming facilitation, Balota and Lorch (1986) also used RL differences between the means of related and unrelated words as a measure of priming facilitation, and Ray and Bly (2007) used RL differences from a LD task to measure facilitation of three categories of information. In addition to these examples, many studies have made use of tachistoscopic recognition time differences between related and unrelated words as evidence of priming (e.g., Neisser, 1954; O'Neill, 1956; Rouse & Verinis, 1962; Winnick & Daniel, 1970).

The scrambled phrase task was used as a priming tool because it has been demonstrated to produce lasting measurable priming in previous research (Banaji, Hardin, & Rothman, 1993; Bargh, Chen, & Burrows, 1996; Epley & Gilovich, 1999; Kawakami, Dovidio, & Dijksterhuis, 2003; Kûhnen & Hannover, 2000; Lepore & Brown, 1997; Randolph-Seng & Nielsen, 2007; Shariff & Norenzayan, 2007; Srull & Wyer, 1979), although in previous research that has used this task priming was measured by more gross behavioral indicators, such as walking speed, performance on a psychometric test, and the rating of behaviors on social dimensions of a fictitious person in a vignette, as described in Chapter II. These types of measures were not chosen for this research because it seemed more likely that they might also be influenced by conscious intention, whereas the LD task decisions are made so quickly that intentional influences should be minimized. I believe that a greater number of categories can be memorized intentionally than unintentionally, and it is the unintentional category priming capacity that is the focus of this research.

> Through the use of a postexperimental questionnaire, Bowers and Schacter determined that subjects who exhibited awareness of the relation between the completion test and the study list showed higher completion rates following semantic than nonsemantic study tasks, whereas subjects who remained unaware of the study-test relation showed equivalent priming following the two study tasks. (Schacter, 1992, p. 246)

Previous research has also used short complete sentences instead of phrases as was used for the research reported here. Creating a context from which each prime word was defined was essential to ensure that each category was primed with 10 priming experiences. A clear context could not be ensured unless phrases, rather than complete sentences, were used. For example, the strong associate of *fruit*: *produce*, was made clear using the scrambled phrase, *produce, sold, also, the,* to specifically refer to that category, so that categories such as *create* did not also occur to the participant.

The analysis conducted on the data was a between-item design, for the overall test comparing primed and unprimed RLs from the LD task. Nonwords were included in the LD task to provide its activity, that of making word-nonword decisions. The nonword RLs were not included in the analysis, though, because that comparison was not needed to determine the number of categories primed. Given the statistical power target value

(80%), the alpha-level (.05), and the effect size from previous research, the number of participants needed were determined.

Setting and Sample

The sample was a convenience sample gathered from individuals in Walden University's Participant Pool. A convenience sample made this study a quasi-experiment rather than a true one, because every member of the population to which the results apply did not have an opportunity to participate. Making use of a convenience sample would not be likely to have any significant impact on the validity of the results, although they are applicable to the population from which they were obtained with the greatest confidence.

Walden University, established in 1970, is a regionally accredited institution of higher learning that provides online courses to students in Bachelor's, Master's, Post-Master's, and Doctoral programs. Its Participant Pool is an online "virtual bulletin board" that allows Walden researchers to "post their studies … and those members of the Walden community who are interested in participating in research can visit the site to see if there are any studies in which they would like to participate.' (Walden University, no date).The Walden Research Center reported that because every Walden student is a potential Participant Pool member, the characteristics of the pool are those of the student population. The results of Walden's student survey, with data gathered during 2010 and 2011, showed that 77.4% of its students, both undergraduate and graduate combined, were female and slightly over 94% were between the ages of 24 to 59. Sample characteristics are provided in the Results Chapter. The only restrictions were that the participants be native English-speaking, have no impairment that made it difficult for them to respond by quickly pressing keys on a keyboard, and they must be 18 years or older.

The effect size obtained should have been predictable in advance of conducting the experiment from previous research that utilized similar tasks to prime and measure priming. The number of priming experiences needed, the number of phrases for each category in the scrambles phrase task, could ideally be estimated from previous research that used differing numbers of priming experiences using similar tasks and measurement methods, but ideal is difficult to come by. Priming tasks similar to the one used in this research have been successfully used in many studies (Banaji, Hardin, & Rothman, 1993; Bargh, Chen, & Burrows, 1996; Fazio, Sanbonmatsu, Powell, & Kardes, 1986; Kûhnen and Hannover, 2000; Kûhnen, Hannover, & Schubert, 2001; Randolph-Seng & Nielsen, 2007 ; Srull & Wyer, 1979), but priming experiences were not consistent and measurement tasks were dissimilar. In studies that have used similar priming tasks, measurement was made with behaviors such as walking speed and cheating in a game, for instance, rather than measures such as LD RL.

Ray and Bly (2007) provided research that can be used to estimate both an effect size likely to be obtained, a number of priming experiences, as well as a sample size. Their research primed three semantic categories by presenting 10 words for each category for which participants made “liking” decisions (p. 75). Previous research has found that the amount of time, the depth of processing, or degree of activation, that results from each priming experience influences the extent of the resulting facilitation (Becker, Moscovitch, Behrmann, & Joordens, 1997; Craik & Tulving, 1975). While there is no precise way of measuring this, except by measuring the resulting priming effect, the scrambled phrases experiences should produce at least as much participant investment as that resulting from the *liking* experiences in the Ray and Bly research; past research reported that used scrambled sentences produced significant priming, and Craik and Tulving (1975) showed that deciding if a word fit into a sentence produced stronger memories than phonetic, rhyming, or categorization tasks.. Ray and Bly obtained a .73 effect size ($F(2, 22) = 28.75$, $p < .001$) between related, unrelated, and nonword response latencies with 12 participants primed with 10 priming experiences for each category using a *Liking* task, and measured priming with a LD task.

For the present research, not wanting to overly tax participants, to help ensure that each participant completed the scrambled phrase task, 10 priming items were presented for each category. The priming in Ray and Bly (2007) produced a significant difference between target words and unrelated words ($t(11) = 4.20$, $p = .0005$) with 12 participants. Wilson Van Voorhis and Morgan (2007) recommended that sample sizes of 14 participants are sufficient for effect sizes of .80, so, erring on the side of caution, 20 participants composed the sample in the study reported here.

The scrambled phrase task was intended to influence performance on the lexical decision task. The amount of influence, priming, was unknowable in advance, and was likely to be different for each participant. Internal consistency for the tasks would depend on the responses to the selected words priming and measuring the categories intended. Because the words that provided these functions had been selected from a large free association study (Nelson, McEvoy, & Schreiber, 2004), and were provided by participants in that study in response to the category names, or the category names were produced in response to the words, they were likely to elicit the same responses. Likelihood being defined by the associative strengths found in the Nelson et al. study.

Instrumentation and Materials

The study description, informed consent agreement, optional information request, task one instructions, task one, task two instructions, task two, and a thank you screen were presented as web pages, presented in that order, and response data, including the time and date that the “I agree to participate” button on the Informed Consent Agreement was clicked, was sent to an Internet hosting server and later retrieved. Potential participants were informed on the Informed Consent Agreement screen that “You can end your participation at any time clicking the ‘x’ on any of the screens involved in this study to close the browser window, and of course there is no penalty if you decide to do this. Any information you provided, including task responses, will be deleted.” The final thank you screen provided this candidate’s email address, and offer a downloadable copy of a summary report for participants who want more information about the study. Instructions were provided for the participant to print the consent agreement, and an email address is provided if they had difficulty with that, or they had questions before participating: “If you wish to make a copy of this page, the Informed Consent Agreement, you can click the File menu of your browser, and select Print. Sometimes the File menu isn't visible, but pressing the ALT key should show it. Contact me at the email address below if you have difficulty with that, or have any other questions. You can do this before proceeding." A phone number and another email address was also provided if there were questions about participant rights.

Experimental Tasks

The tasks were presented on each participant's computer, over the Internet, using browsers such as, Microsoft's Internet Explorer, Mozilla's Firefox, Google's Chrome, and Apple's Safari. They were created using HTML and JavaScript computer programming languages which are commonly used for the development of browser pages, using Microsoft's Visual Studio 2010 development environment. Pages were tested for compatibility with the many browsers and versions by the development environment's accessibility tests, and were tested on a variety of systems to ensure that the programming provided similar experiences for each participant, using computers running different operating systems and using different browsers. The programming on the server-side, which received and temporarily store the data, was developed in Perl, again, a language designed for these types of transactions. The tasks were tested numerous times on a variety of Windows systems and Windows compatible browsers, including a Windows version of Apple's Safari and a new Apple computer, and consistently provided the data they were designed to provide. Data processing problems were never found, but there are relatively minor display differences. For example, the Apple system and its latest Safari reduced the space between lines of text, which was corrected by increasing that distance. In case there is a display problem, which is possible because it is not feasible to test the presentation on each participant's system, the Study Presentation page stated: "If you cannot complete the experiment because the pages do not display correctly, please let me know. Email the name of the operating system and browser you are using to me at edward.hahn@waldenu.edu," so any difficulty could have been corrected, or alternatives for the participant might have been considered. A display problem severe enough to warrant this action was not been seen during testing, and so it is believed to be unlikely. No problems were reported.

All words in both tasks were presented in uppercase, Arial, 15pt font. A white background with black font color was used for the presentation, and a medium cyan background was chosen to provide non-distracting and easy to view presentations. The programming provided an automated process. The cursor is automatically positioned in the text field in which the responses to the scrambled phrases are entered, to minimize distracting activities, and the *w* and *n* keys to be pressed to indicate word or nonword in the LD task are far enough apart and are logically related to their meaning in the task, which should help prevent erroneous responses. Pressing either key initiates the recording of the response and the presentation of the next letter-string, following a 5sec random delay. This random delay prevented participants from pressing keys in a rhythm, which was found to be a possibility during task development. At the beginning of both tasks, participants had to only click a button using their mouse to begin, after reading the tasks' instructions, then they pressed ENTER on their keyboard after entering each unscrambled phrase, and the *w* or *n* key to indicate LD responses. Data was automatically sent back to the servers at the end of each task, and no record of responses remained on participants' systems.

Selection of Categories and Related Words

Category Norms vs. Associates from Free Association Studies. Because the goal is to prime categories, using exemplars provided by category norming studies might seem reasonable, and past category priming research has used these exemplars, but psychological categories are not simply composed of logical examples, as discussed in Chapter II.

There would be two problems involved in using category exemplars in a study such as the one reported here; the first is that the associative strength of the words cannot be accurately determined. One study, for example, that investigated priming of multiple categories, Ray and Bly (2007), used category exemplars from Battig and Montague (1969) as primes and also to test priming in a LD task. Another priming study, Hines, Czerwinski, Sawyer, and Dwyer (1986), used the first and fifth exemplars provided by participants from Battig and Montague, and Graf, Shimamura, and Squire's (1985) reported that,

> The items selected were not ranked among the 10 most frequently produced exemplars for a category, but each item was listed as an

> exemplar by at least 10 subjects in the sample of 400 subjects used to collect the normative data. On the basis of overall production frequency, the average rank of the selected category exemplars was 23.9 (range 11-46) in the Battig and Montague norms. (p. 392)

Table 1 (see Chapter II) shows the difference between category norms and associates from free association clearly. *vegtables* and *sweet* were produced much more often than *lemon* and *watermellon*, for example. Words with stronger associations to the categories, but were not exemplars, are bypassed by participants in category norming studies. A strong associative relationship was needed for the strongest priming, and free association studies allow for the identification of the strongest. The second problem with using category norms is that the direction of association is wrong to most effectively produce priming.

The efferent proportion, efferent associative strength, reported by Nelson, McEvoy, and Schreiber (2004), termed forward strength in that research, is the proportion of participants who produced an associate in response to a cue word. It is also the probability that a participant in the study would produce a particular associate when a cue word was presented. It is a measure of the likelihood that the cue word would produce the associate, but it is not the probability that the associate would produce the cue word. Category norming studies only identify words with efferent associative strength. Presenting an associate with a strong efferent strength from the cue word is not the associative direction needed to prime the cue (category) word and its associated category of information. Instead, afferent associative strength is needed. That is the probability that the cue word would produce the associate is presented. Category norming studies cannot provide words with associative strength in the direction needed for most effective priming. Simply selecting the words most often produced in a free association study would have the same problem.

The Nelson, McEvoy, and Schreiber (2004) data used in the research conducted was provided by those researchers organized around efferent strength. The 72,176 rows of data in the text files they provided are arranged in this manner shown in Table 2.

Table 2

Responses to the Cue Word school

Cue	Response	Normed	nG	nP	FSG	BSG
SCHOOL	WORK	YES	196	25	0.128	0.020
SCHOOL	COLLEGE	YES	196	22	0.112	0.238
SCHOOL	BOOK	YES	196	14	0.071	0.055
SCHOOL	BUS	YES	196	14	0.071	0.079
SCHOOL	LEARN	YES	196	13	0.066	0.167
SCHOOL	STUDY	YES	196	12	0.061	0.094
SCHOOL	STUDENT	YES	196	8	0.041	0.122
SCHOOL	HOMEWORK	YES	196	7	0.036	0.091
SCHOOL	TEACHER	YES	196	7	0.036	0.128
SCHOOL	CLASS	YES	196	6	0.031	0.203
SCHOOL	EDUCATION	YES	196	6	0.031	0.315
SCHOOL	USF	NO	196	6	0.031	
SCHOOL	HARD	YES	196	5	0.026	0.013
SCHOOL	BORING	YES	196	3	0.015	0.020
SCHOOL	CHILD	YES	196	3	0.015	0.000
SCHOOL	HOUSE	YES	196	3	0.015	0.000
SCHOOL	DAY	YES	196	2	0.010	0.000
SCHOOL	ELEMENTARY	NO	196	2	0.010	
SCHOOL	FRIEND	YES	196	2	0.010	0.000
SCHOOL	GRADE	YES	196	2	0.010	0.118
SCHOOL	TIME	YES	196	2	0.010	0.000
SCHOOL	YARD	YES	196	2	0.010	0.000

Note: Candidate constructed table from data reported by Nelson, McEvoy, and Schreiber, (2004) The rows are actually much longer, containing 31 data items, but only the beginnings are needed to illustrate the selection process. The excerpt shows the rows that resulted from the cue word *school*. The word to the far left was the cue and the next word is an associate produced by the group of participants who were presented with the cue word. As provided by Nelson et al., the listing is organized by efferent strength, with the first associate listed, *work*, having been produced by the greatest number of participants; the efferent proportion is the 0.128, which is the proportion of 25/196, the number producing the associate divided by total group size. The range of possible values for both efferent and afferent associative strength is 0.0-1.0. If *work* is presented to a participant, the 0.128 is not the likelihood that the word, or category, *school* will be produced or activated. It is the likelihood that *work* will be produced, or activated, when the word *school* is presented. *school* is a strong prime for *work,* but *work* is not the strongest prime of *school*. In the format the researchers provided their data it is difficult to see, but CAMPUS, which was not given as a response to *school*, is the strongest prime for *school*, with an afferent strength, the probability of activating *school*, of 0.466; the probability of producing *school* when *work* is presented in only 0.020. There are 183 additional cue words scattered throughout the database provided by Nelson et al. with afferent values ranging from 0.011 – 0.466 for *school*. Words such as *campus, semester, education, principal, educate, backpack, bookbag*. The strongest afferent values, would not be identified in a category norming study, and most would not be found by simply using the most frequent responses from a free association study.

The direction of associative strength needed for LD target words is the opposite of that needed for priming. Targets must have strong efferent associations with the category word to show that priming has occurred. After a category has been primed, words with strong efferent strength have been activated; just as they are when a cue word is presented to a participant in a free association study. This is the reason that the response word occurs to them. Once the category is primed, shorter RLs for these words in the LD task indicate this, and this resulting facilitation can be used to determine priming effect. Because the aim is to reduce RL by priming efferent associates, LD words need to have a strong efferent association to the category. They should be words activated when the category is activated. These words are those listed with the cue word in the database provided by Nelson, McEvoy, and Schreiber (2004), *work, college*, etc.

Selection Process. Initially, a particular type of noun, place labels, was chosen, simply by perusing the list of nouns, to try to locate categories from the Nelson, McEvoy, and Schreiber (2004) database that had some commonality. Ten categories were selected by first creating a spreadsheet that contained nouns that represented place labels, such as hospital, school, etc.. This group of words was sorted by total number of efferent associates, and, because 10 efferent associates would be needed in the LD task, the first 10 efferents from each of the potential categories was processed by an Excel macro developed to report the number of interrelationships between associates. Those with the smallest number of interrelationships would be the most unrelated. Inspection of the associates showed that the mean associative strength of these was very low, and so the process was used again on all nouns. Again, 10 were selected that had more than 10 efferent associates, and the ten with the highest efferent associative strength were chosen. This produced a list of 10 nouns: *baby, clothes, boat, car, doctor, television, fruit, bread, hair,* and *school*. Following this, it was decided that using 100 scrambled phrases in the priming task (10 phrases for each category) might be too taxing on participants and attrition might be too high. Five categories have particularly similar efferent and afferent strength, and so were selected: *bread*, *fruit*, *hair*, *school*, and *television* (see Figure 2). The mean efferent strength of the words used to prime a category in the scrambled phrase task was expected to reflect the amount of priming produced for each category, so having similar mean associative strengths would hopefully increase the likelihood that they would prime equally.

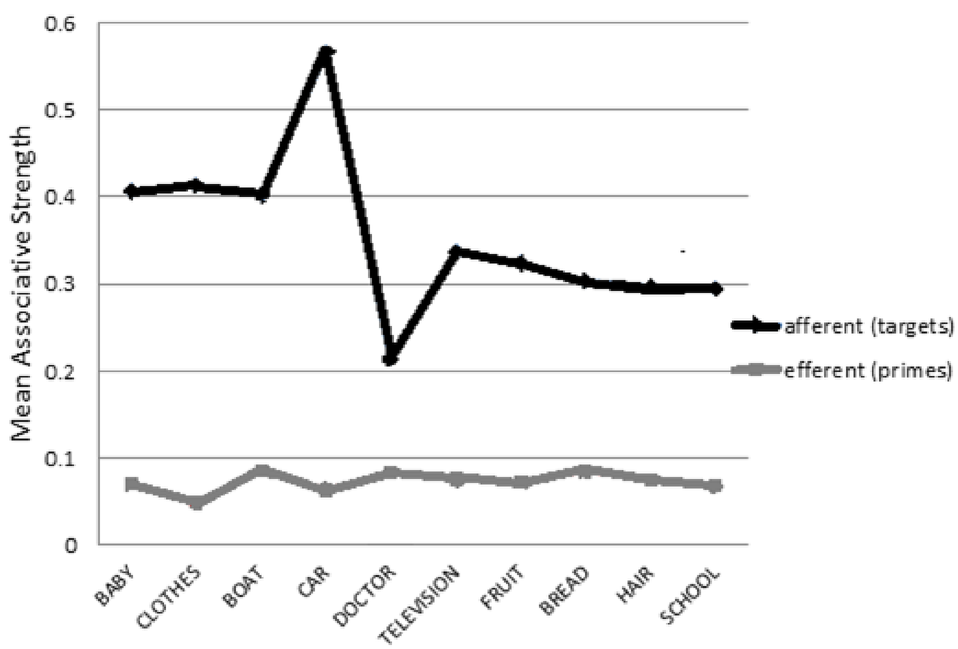

Figure 2. Mean associative strengths of the ten unrelated categories.

Because the phrases to be unscrambled would help define the meaning of the priming word, interrelationships between them were not considered, but a few that were difficult to create scrambled phrases clearly designating the category were replaced with other afferents of lower associative strength.

Unrelated Words. The words to be used for the unrelated condition (n = 10) were chosen by selecting associates from cue words in the Nelson, McEvoy, and Schreiber (2004) data which were not associated with any of the categories to be primed.

Controlling for Frequency. Previous researchers has found that the higher the frequency of words in common usage, the smaller the effect of priming. No research has been located that has established the reason for this, but frequency in common experience might be considered repeated priming. It is likely that there is a maximum priming effect, with an asymptotic relationship between the number of priming experiences and priming effect near the top of the curve, as was considered in Chapter II. The most common words are continually primed, which maintains them in a ready state to be recognized. Although seasoned researchers do not often freely conjecture, as does an enthusiastic PhD candidate, it seems reasonable to think of this type of modification of readiness as learning, resulting from relatively permanent changes, for instance, in synaptic communications within a conceptual pattern. At any rate, this decreased impact of priming would produce a decreased priming effect in the data of the experiment. Controlling for this simply requires that the frequencies of the related and unrelated words to be compared are similar, although lower frequency words in each case would probably be ideal, because their priming would be expected to produce the greatest effect on their recognition times, producing a greater difference their RL, as they have in past research. Frequencies reported in the Nelson et al. data were taken from Kucera and Francis (1967). They have a range of 1-9999 out of 1,000,000. The mean frequency of the target words used in the research reported here was 113.59 (standard deviation, (SD) = 169.81). The unrelated words selected have a mean frequency of 112.9 (SD = 0.88). Because there was no reason to duplicate the standard deviation of the frequencies in the unrelated words, words with frequencies ranging from 112-114 were selected. The category words: *bread, fruit, hair, school,* and *television*, have a mean frequency of 153.2 (SD = 194.95).

Nonwords. Nonwords (n = 20) were selected from those provided by Borowsky and Besner (1993). The letter-strings to be used were chosen to be dissimilar to any of the associates used in either the scrambled phrase or LD tasks.

Data Collection, Preparation, and Analysis

Data Collection

Ten phrases were used to prime each category, each containing a strong afferent associate of the category, and RL from 10 words with strong efferent associations in the LD task were used to measure the priming. Priming phrases for each category were presented sequentially in the scrambled phrase task, and the words associated with each category were presented randomly in the LD task, to minimize the likelihood that participants would realize that a particular category is being represented.

The scrambled phrases task were presented on each participant's computer, or one of their choosing, over the Internet. This task is similar to the first use of the task by Srull and Wyer (1979), whose participants created complete sentences using three of four words presented. Participants in the study reported here were instructed to create a sensible phrase from three of the four words and type it into a field provided as quickly as they can without making errors. Each participant created 10 unscrambled phrases for each of the five categories. There were 50 scrambled phrases for each participant to unscramble. The phrases within a category were presented sequentially, so the phrase sequence were the same for each participant. This allowed the strongest associate of a category, the associate that is most likely to activate it, to be presented first, hopefully increasing the likelihood that weaker associates presented in each category's other nine phrases were be interpreted within the desired context. Categories were presented randomly.

Immediately following the scrambled phrase task, the LD task was presented. Words were presented randomly to each participant, and word-nonword responses were made by pressing either the *w* or *n* key on their keyboards. The time from when a letter-string is presented to when either a *w* or *n* is pressed on the keyboard, by the participant making a word-nonword response, were the RL used to measure priming effect. There were 10 words for each category, 10 words unrelated to any of the categories, and 20 nonwords, plus five practice trials, giving a total of 85 words. Participants were asked to respond as quickly as possible without making errors. The need for accuracy was reinforced by flashing the screen red when an error is made, and flashing the screen green when a key other than *w* or *n* is pressed. The start time for the latter trial is also reset, the selected word for that trial stays on the screen. Each time this occurs, a number is incremented and, if that number is greater than zero, it is appended to the end of the returned data response line. The participant was unaware that these errors are counted (see Appendix E). All response latency measurements were made in milliseconds.

The web pages that presented and transferred participant responses also recorded the time that the participant leaves each page. This helped determine if a delay occurred between the priming and measurement tasks. Too lengthy a delay disqualified one set of the data (see the Results chapter). Returned participant responses also provided data that might cause data to be excluded from analysis. This information is reported in the Results chapter. Each response is stored along with a participant number, which helped maintain data integrity throughout the analyses (see Appendix E: Returned Data Examples).

Because the tasks to be used are essentially the same as those used previously in research to prime and measure the priming of categories, and the words were acquired from a well-known study (Nelson, McEvoy, & Schreiber, 2004) to be utilized in these have been used in previous studies (e.g., Yap, Tse, & Balota, 2009), and the selection of associates has been meticulous and thoroughly considered, the construct involved in this research, and conclusions drawn, are likely to be as anticipated and valid.

Data Analysis

Data analysis will involve both a between-participant design and a within-participant design, and the latter will produce the main results of the research[2]. Using the Statistical Package for the Social Sciences (SPSS v21), the overall between-participant's design analysis will consist of a single one-way ANOVA, comparing the means of the related, unrelated, and nonword[3] lexical decision (LD) response latencies (RLs) from all participants.

Procedures for Maintaining Data Integrity during Analysis. A system of moving and verifying data during analysis has been developed with numerous trials using randomly generated data. Additionally, a procedure has also been developed to move data from the completed SPSS analyses to a formatted Excel spreadsheet, where tallying of significant results was automatically completed[4]. These automated calculations will serve as first calculations and save time by allowing the recalculations to be verifications. These procedures will help ensure that data was faithfully transferred and analyzed with minimal opportunity for error.

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[2] This plan was later altered because the Gaussian components of the distributions had to be separated to measure the priming effect, and it was determined that 10 RLs per individual from the LD task were too few to provide for reliable identification of the Gaussian components of the unprimed and five primed distributions for a within participants analysis. As a consequence, a post-hoc Dunnett's Multiple Comparisons of the Gaussian components of the grouped data that followed a primed vs. unprimed one-way ANOVA provided the main result of this research. Gaussian components were extracted to remove the influence of strong exponential components in the unprimed and five primed distributions (see Chapter IV).

[3] Because comparing the nonword RL would not contribute to testing the hypothesis in this study, this plan was altered, and the nonword RLs were not included in the analysis.

[4] This plan was later altered, see note 3

Data Storage. Data is stored on DVDs for five years following the study. The files are stored encrypted and password protected, using WinZip 12. Only this candidate will have access to the locked storage container in which the DVDs will be stored.

Excluded Data. RLs that are significantly short or long were excluded from analysis, to reduce the effects of erroneous responses on the results. In the study reported in Ray and Bly (2007), RL responses from their LD task which were less than 399ms[5] or more than 2000ms were excluded from analysis. Balota, Yap, Cortese, and Watson (2008) excluded responses which were faster than 200ms and slower than 2000ms. Excluding the faster rates would decrease erroneous RL due to impulsive responding, and excluding those longer than 2000ms would decrease erroneous RL due to distractions and hesitations.

Protection of Human Participants

Participants in the my study were not be in danger of any physical or psychological harm as a result of participating. The priming phrases that were unscrambled and the words selected for the lexical decision task are common words and refer to categories of information commonly accessed daily by individuals. The Informed consent Agreement informs potential participants of this with: “There are no risks to you involved in participating.”

Response files were transferred to DVD discs and removed from the Internet connected computer. These DVDs are stored in a location to which no other person has

[5] Removal of the lower values was not conducted after further research indicated that the lower values would most likely provide evidence of priming (the Gaussian components).

access. There is no identifying data requested from participants. Some demographic information was requested, but it is optional. This was separated from the other data, and stored, encrypted and compressed with a password required for access.

Summary

This chapter provided descriptions of the methods and materials used in the research reported here, and justified choices made citing past research. It also presented and justified the research design, and the reasoning and evidence that produced the sample size, as well as a description of the population from which it was drawn. Characteristics required in participants were also provided. The Instrumentation and Materials section described how the categories, words, and nonwords were selected, and from where they were obtained, as well as specifics of the data collection procedures and planned analysis. Finally, it described security measures to be used to protect participant data, and the impact that the treatments might have on participants.

Chapter IV will provide a description of the data collected, and the results of its analysis.

Chapter IV: Analysis and Results

Introduction

The research reported here was an attempt to measure implicit category priming capacity. That is, it attempted to measure the mean number of categories of information that can be implicitly primed and measured a few minutes later in a group of individuals. Priming refers to a facilitation of memory access or response production as a result of recent prior access to the same information or response systems. Priming is, roughly, explicit if the prior response was the focus of conscious attention and implicit if it was not. For example, memorizing words produces explicit priming and the facilitation of access to the word *research* by reading the word at the beginning of this paragraph was implicit, unless you stopped at that word and considered its meaning. Reading that word a second time was probably a little faster, because systems/representations used to read it were accessed moments before; the response was practiced. Generally, the more often a representation or process is accessed, the less facilitation is gained. Another example would be the word *menu*. Sitting at a table in a restaurant, the word has a completely different specific meaning and primes a completely different category than when composing a document in a word processor. They have a general category of meaning in common, but the more specific, contextual, categories are completely different, and this makes the potential items listed and the object's form completely different. As this example shows, in at least some situations, context is probably equivalent to category.

In this research, access to five categories of information (*bread, fruit, hair, school, television*) were implicitly primed, and the resulting facilitation in a subsequent access to the categories' information was measured. The number of categories successfully primed was found by comparing the mean response latencies exhibited by participants accessing each of the primed categories to the mean response latency accessing categories (words) that were not primed. The difference provided a measure of priming strength, and was measured in milliseconds (msec).

Based on indications from past research (Graf, Shimamura, & Squire, 1985; Ray & Bly, 2007), it was hypothesized that the number would be less than five, possibly two to three (the study's hypothesis). This chapter will briefly review the two tasks that participants completed in this study. Participant characteristics are provided, and the data preparation, analysis, and results are reported.

Tasks

Five relatively unrelated categories of information were identified in the Nelson, McEvoy, and Schreiber (2004) South Florida database (*bread, fruit, hair, school, television*). Unrelated categories were chosen because relatedness among the categories would reduce the number being primed by combining them. Unrelated categories are those which were found to have the fewest responses in the Nelson et al. study in common.

Two tasks were presented to participants. The tasks were presented over the Internet. Data collection occurred between June 3, 2013 and August 8, 2013, and proceeded without alteration to the tasks that had been prepared.

Task One: Scrambled Phrase Task

In each problem of the first task, a scrambled phrase task, participants were presented with four words, one of which was associated with a category to be primed, and asked to construct a sensible phrase with three of them. Accessing the meanings of words in this first task provided the priming. The categories were randomly presented, and participants completed 10 phrases to prime each category. Ten phrases were presented for the first category that the presentation program randomly selected. After the participant completed these, another of the five categories was randomly selected, and 10 phrases were presented to the participant to prime that category. This process continued until all five categories had been presented. There was no way that a participant could know when a new category's phrases were being presented. To the participant, one scrambled phrase was presented after another, until the 50 had been completed. Presenting the phrases for each category in this way, grouped, as opposed to presenting a phrase to prime one category, then presenting a phrase to prime another category, is termed a blocked presentation, and this has been found to increase priming strength (Rappold, & Hashtroudi, 1991).

Category Presentation Position in Task One

Presentation position, particularly whether a category is presented first or last to a participant, could have an impact on priming strength measured in the lexical decision (LD) task. It has been found that the first word in a list to be explicitly memorized is recalled slightly more readily then words presented after that one, and the last word presented is recalled most readily (primacy and recency effect, Bjork, & Whitten, 1974). The same might be true when implicitly priming categories. The category that is presented first might show greater priming than the ones presented second and third, and the one presented last might show the greatest priming. Alternately, the first category presented is followed by four more categories before priming is tested, so it could show the least priming. Table 7 shows the frequencies of category presentations by presentation position. That is, the number of times each category was randomly presented first, second, third, fourth, and fifth to the participants during the scrambled phrase task. For example, category two (fruit) was presented seven times as the first category and category four (school) was presented six times as the first category.

Table 3

Category Presentation Positions and Frequencies

Presentation	Category				
position	bread	fruit	hair	school	television
first	2	7	2	6	3
second	3	4	2	8	3
third	7	4	4	1	4
forth	8	1	3	1	7
fifth	0	4	9	4	3

Task Two: Lexical Decision Task

Immediately following the scrambled phrase task, a lexical decision task (LD) randomly presented 50 different words associated with the primed categories in the Nelson, McEvoy, and Schreiber (2004) database (10 each), 10 words not associated with the primed categories, and, 20 pronounceable nonwords (from Borowsky and Besner, 1993, see Appendix D). The nonwords were not included in the analysis, because they were not needed to test the study's hypothesis.

Each word in the LD task was presented during a 5sec random period following the preceding response. Participants were asked to decide as quickly as possible if the presented letter string was a word or not, providing a response by pressing either the *w* or *n* key on their keyboards. The means of these response latencies (RLs), the time from when a word was presented until the participant pressed a *w* or *n* key, of the unprimed and five primed categories were compared to measure priming effect.

Participants

The tasks were presented over the Internet to a total of 23 anonymous participants, self-selected by way of Walden University's Participant Pool. Participant ages ranged from 27-54 years. (M = 44.4 years). Demographic information was optional, and one participant did not specify their gender. Of those who did, three (16%) were male. Participants in the sample were more highly educated than average, because they were university students, so the results might not be comparable to the general population. Mean education reported was 18 years and the range was 10-25 years.

Data Integrity and Data Cleaning

Participants completed the tasks without supervision, and with a high accuracy in the LD task (mean errors = 3.2, 4%). As a comparison, in experiment one in Yap, Balota, and Tan (2013), testing for short-term priming, the LD error rate was 5.7% in their first experiment and 6.3% in their second experiment.

Although participants completed the LD task with few errors, generally, one set of participant data was removed due to excessive errors (25/60, 41.6%). This number of errors could indicate that the participant was distracted or had some difficulty completing the task, which might produce RLs that counteract or exaggerate priming measurements. In the remaining data there were a total of 64 errors, including nonword errors. Fifty seven involved nonwords (12 from one participant). There were only six primed word errors (two for one participant, and one apiece for four), and one for an unprimed word. Error RLs were not removed for analysis (7/1200, 0.5% of analyzed data, mean RL of the seven in the analyzed data = 653), as is usually done (e.g., Ray & Bly, 2007), although errors seem most likely to be related to decision processing rather than speed of perception, which is the variable of interest here, they were included in the analyzed data.

In addition to the set of data removed due to a high error rate, one set of participant data was removed as a result of extended time between tasks, 8min 14 seconds,(M = 42 seconds[6], median = 38 seconds), 11.4SD above the group, and one set was removed due to an extended time in the scrambled phrase task, over 24 minutes (M =

[6] for 20 participants included in the analysis

9 minutes 11 seconds[3], median = 8 minutes 48 seconds), 2.6SD above the group. These were removed because implicit priming has been found to be short-lived (Swinney, 1979. Although the priming is expected to be more lasting due to the blocked/repeated priming technique used here, the excessive time between priming and measurement in these two cases might be sufficient to reduce the priming effect measured in the group. Trimming sets of participant data that are identified as outliers from the group has been done in other research (e.g., Banaji, Hardin, & Rothman, 1993), and seemed reasonable to reduce the influence of extraneous variables (e.g., hesitations, distractions, not conscientiously following the instructions.). This left 20 sets of data for the analysis.

Data Preparation

Outliers and Transformations

Figures 3 and 4 shows the similarity between the raw data primed and unprimed data distributions from the 20 participants, as well as the distributions' strong positive skews. Response latencies in the raw data[7] (in the data from the 20 participants) ranged from 189msec to over 4000msec. The plan to trim RLs < 399msec was not conducted, as a result of further research into distributional analysis (see Gaussian Distributions) that indicated that lower RL values are the most likely to show priming effects. Instead, the 189msec RL and all RLs > 2000msec were removed from the data, and replaced by the participant's category trimmed mean, which Osborne and Overbay (2004), citing Anscombe (1960), referred to as a "common robust estimation method." A trimmed

[7] Original data from which outlying low and high scores have not been removed or altered.

mean is the mean after the high and low outlier values have been removed. This procedure reduces the extreme influence of outliers on the distribution's mean without deleting the response. Changing the outlier values to the trimmed mean retains the responses without altering the distribution's mean, settling on an average category response time for the participant, for the response.

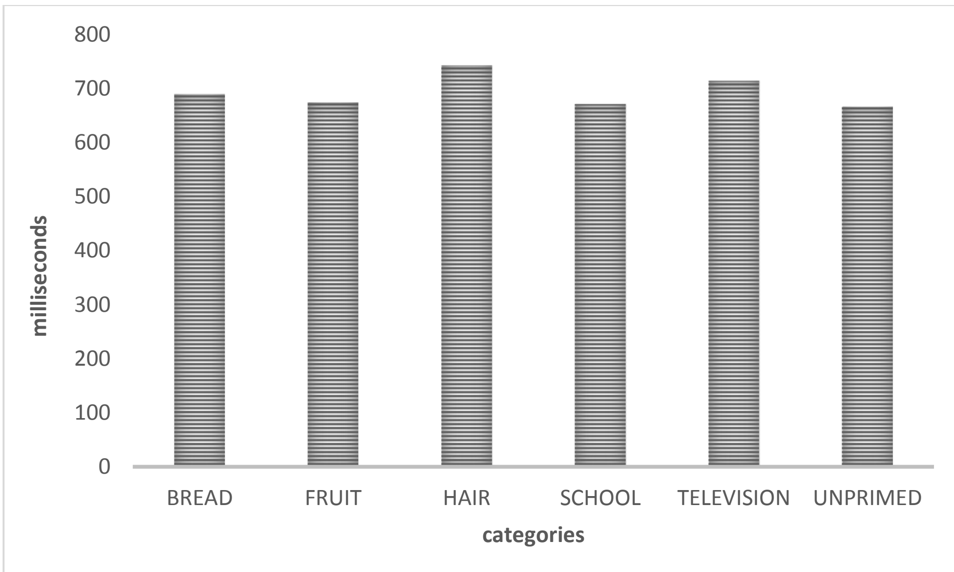

Figure 3. Graph of raw data distribution means.

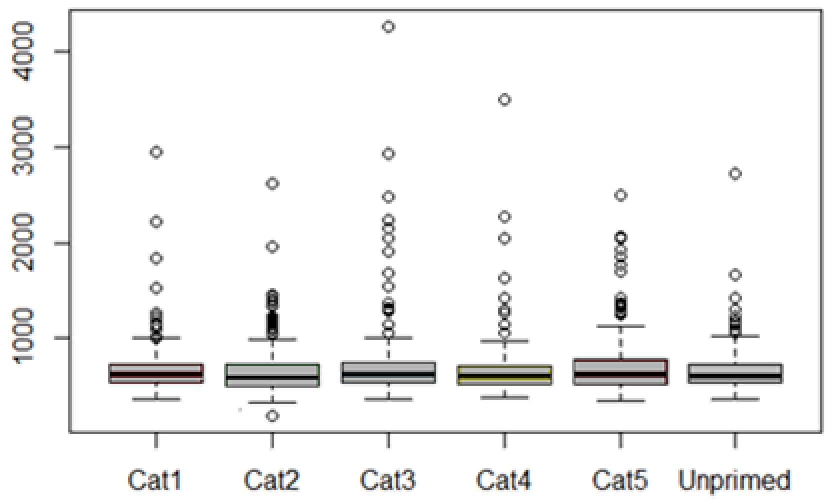

Figure 4. Box plots of raw data categories.

The 189msec RL was trimmed from category 2 (*fruit*) because it was identified as an outlier by a box plot created using SPSS (see Fig. 4). That value was over -3.7 standard deviations (SD) below the mean of the final distribution; far too low to have been a likely valid occurrence for that distribution, and more likely to have been an impulsive response[8].

Finally, the 2000msec upper cutoff was based on procedures common in research that use response time (RT) data (e.g., Balota & Yap, 2011; Ray & Bly, 2007), since the high values likely represent something other than simply the time required for a participant to recognize a word and make a response, such as conscious decision-making, hesitations, or distractions. Researchers in the past have used slightly different values for the high cutoff. Ray and Bly (2007) also planned to use 2000msec (although none

[8] Excel could not report the probability of its occurrence; it produced an error, so the probability that it is a value within the Gaussian distribution identified is beyond 30 decimal places.

occurred in their data). Sometimes cutoffs are based on SDs. For example, Yap, Tse and Balota (2009) trimmed RLs greater than 2.5SD. High outliers in the data from the present study represented 1.3% of the data from the 20 participants. For comparison, the outlier rate ranged from 2.6% to 2.9% in the four experiments reported in Yap, Tse and Balota (2009). In the present study, trimming the high outliers, however, did not completely correct the strong positive skews in the distributions. Continuing to refine the trimming could possibly resolve the problem, but it is difficult to estimate where the upper limit of valid RLs lies; RLs not tainted by conscious decision-making, hesitations, or distractions.

As a result of this dilemma; data so positively skewed that any priming effects were inextricably buried, a new round of research[9] began to search for some way to extract the recognition portion of the unprimed and primed category RLs. This research discovered that this had been a topic of research for many years.

Gaussian Distributions

Past research has found that RT distributions are typically skewed and represented best by a combination of a Gaussian and an exponential distribution. The Gaussian component is a normally distributed set of values, meaning the data points are independent of one another and individually distributed (iid) or, randomly distributed, as in the left graph of Figure 5, while the exponential component is a series of data points related by some exponential function, assumed to be the influence of some additional variable(s) that distorts the Gaussian recognition/response. For example, instead of y (a

[9] Motivated by the Committee Chairman, Dr. James Carroll, who recommended I consider the all of the RLs.

RL) = x (recognition + some priming effect [or not] + a motor response), the RL would be composed of these same variables plus an exponential influence from some additional variable(s): (recognition + some priming effect [or not] + a motor response + z^n), where z^n represents some variable such as inattention or some response that causes a hesitation (such as a mis-recognition might), resulting in the grouped data distribution as a linear combination of a Gaussian and exponential distribution; an ex-Gaussian distribution; a distribution with a strong positive skew (Spieler, Balota, & Faust, 1996; Whelan, 2008; Yap, Balota, & Tan, 2013).

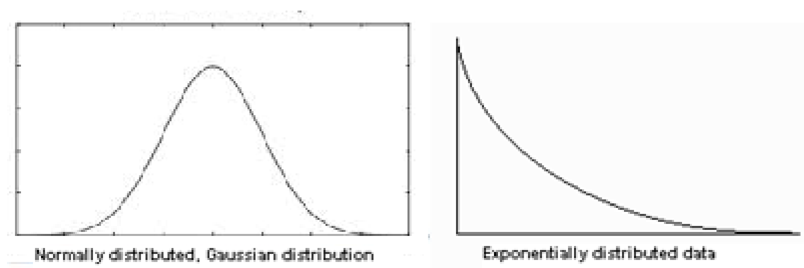

Figure 5. Gaussian and exponential distributions.

Significant differences have been found in the Gaussian components of LD RL data in previous research. Yap, Balota, and Tan (2013), for example, found that, from LD data, "main effects of nonword type … and priming … were significant" for the Gaussian components identified with the, Quantile Maximum likelihood Parameter Estimates (QMPE, Heathcote, Brown, & Mewhort, 2002) [10] computer program, while the comparisons of the exponential components was significant only for nonword RLs (p.

[10] QMPE "typically requires at least 100 sample data points, but … seems to give good results with sample sizes as small as 40" (Brown, Cousinau, & Heathcote, 2004).

144). In addition, Spieler, Balota, and Faust (1996) found that the mean of the Gaussian component decreased in the congruent Stroop condition, which is expected, while the exponential component increased, partially obscuring the difference between the congruent and incongruent conditions[11].

Gaussian components could not be identified in the individual data for a within participant analysis, as had been planned, due to too few data points per individual LD distribution. Although not as useful, and it would not provide a test for the hypothesis of this study, the grouped data might provide the number that can be expected to be significantly primed in a group, which might or might not be related to the implicit category priming capacity.

The QMPE program was used to identify the Gaussian and exponential components in the unprimed and five primed category distributions in the present research. A graph comparing the raw data and the Gaussian and exponential means provided by the QMPE software shows that the exponential components “contributed the largest amount to the overall RL” [12] pattern (see Figure 5 and Table 8). Both the raw data and the exponential components have similar means, whereas the Gaussian means have shorter response latencies for most categories, relative to the Gaussian unprimed mean, and at least two of these appear to be sufficiently different to be significant.

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[11] The Stroop effect is when shorter RLs occur when a color-word (e.g., *RED*) is displayed with the color font named by the word (e.g., *RED* displayed in red font color; congruent condition), as opposed to when it is displayed in another color font (e.g., *RED* displayed in green font, incongruent condition).
[12] Committee Methods Expert, Dr. Thomas Edman

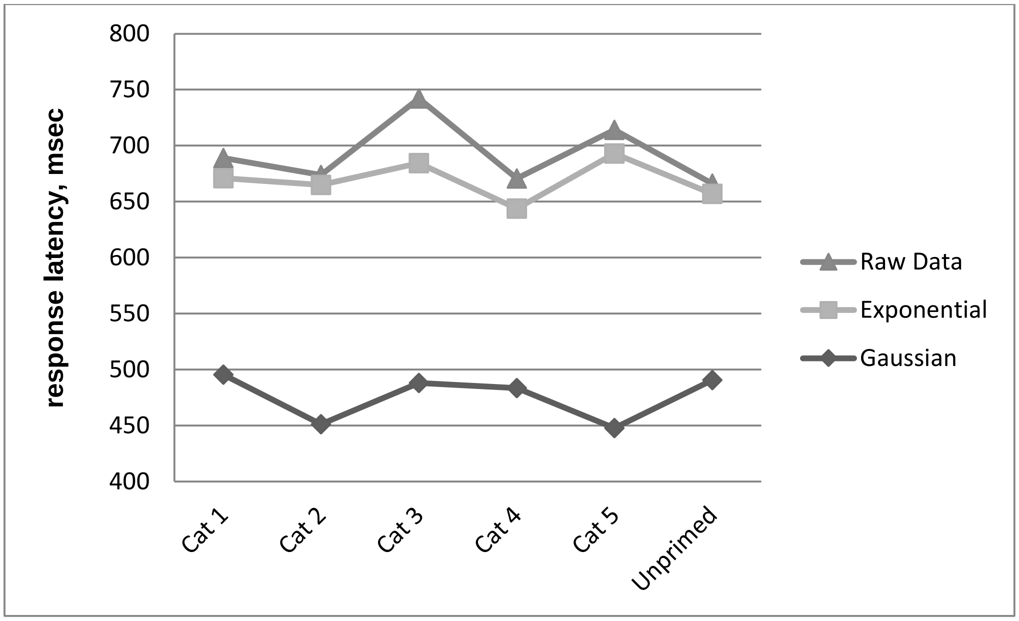

Figure 6. Comparison of raw data, and QMPE exponential and Gaussian means.

Table 4

Raw Data and QMPE Provided Means

		QMPE	
	Raw Data	Exponential	Gaussian
BREAD	689.105	671.005	495.573
FRUIT	673.940	665.061	451.207
HAIR	742.075	684.292	488.156
SCHOOL	670.780	643.736	483.565
TELEVISION	714.160	692.950	447.731
Unprimed	666.195	656.937	490.615

The parameters provided by the QMPE program were be used to construct the pure Gaussian distributions, so ANOVA could be used for comparisons, using,

$$f(x) = \frac{1}{\sqrt{2\sigma\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}},$$

which provides the probability of each RL value. The created distributions (see Appendix F) span roughly -1.7 to 1.7SD, encompassing 99% of the RL range for each category. Both the means and SDs of the created distributions are equal to the QMPE parameters to three decimal places. Figure 6 displays the created Gaussian distributions.

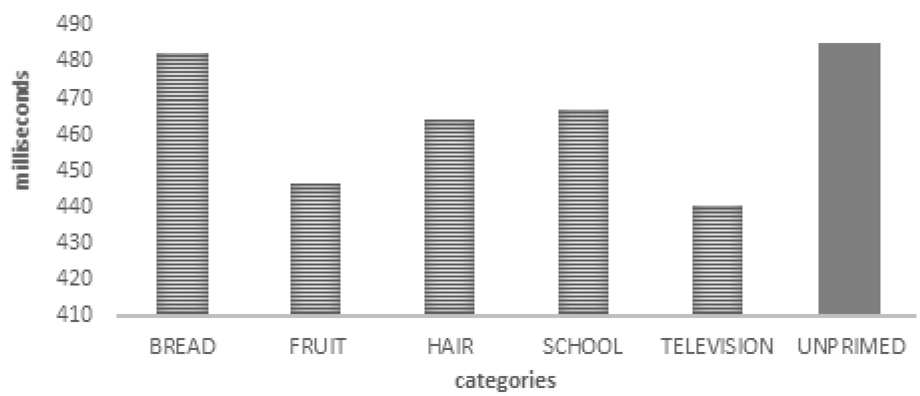

Figure 7. Comparison of Gaussian distributions created using QMPE provided parameters (approximately -1.7 to 1.7SDs).

Results

A one-way ANOVA comparing the created Gaussian distributions was significant ($F(5,329) = 5.313$, $p < .001$). Levene's test, which compares the variances of the distributions, was also significant, ($F(5,329) = 2.980$, $p = .012$), so Dunnett's T3 was used for multiple comparisons. Dunnett's T3 compensates for significant differences in variances. Those results showed a significant difference between category five and the unprimed RLs (Table 9). Priming effect was 34.250 msec, which is the difference between the unprimed mean and the mean of category five (*television*).

Table 5

Dunnett Multiple Comparisons of Gaussian Distributions, All Data

Multiple Comparisons*

		Mean Difference	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Unprimed	Category 1	-13.592	13.074	0.994	-52.767	25.583
	Category 2	30.774	12.588	0.213	-6.941	68.488
	Category 3	-3.056	10.608	1.000	-34.712	28.599
	Category 4	-1.585	10.986	1.000	-34.420	31.250
	Category 5	34.250*	10.827	0.029	1.904	66.595

* Dunnett T3 multiple comparisons test, used when significant variance differences exist.

Figure 7, though, shows that categories two and five (*fruit, television*) were similarly lower than the unprimed. That is, their mean RLs were similarly shorter than that of the unprimed. This difference between means is the measure of priming effect and the measure of interest here. So, visual inspection results appear to indicate that two categories remained similarly primed after a few minutes, sufficiently to produce similar priming effects (differences from the unprimed mean), but a significant difference in variance between the five primed and the unprimed distributions requires that the Dunnett's T3 test was used instead of the standard Dunnett's test. The Dunnett's T3 reduces the degrees of freedom to produce a more conservative multiple comparisons analysis than the standard Dunnett's test.

To test if a standard Dunnett's multiple comparisons test would have found that the two primed categories that showed similar differences from the unprimed in the visual inspection would both have been found to be significantly different from the unprimed, an visual inspection of the graphed variances was made to try to identify which category(ies) were responsible for the significant difference in variance. Figure 8 and Table 10 show that both categories one and two have similar, relatively large variances in comparison to the unprimed.

Removing category one, which has the greatest variance (and is definitely not displaying a priming effect), from the one-way ANOVA produced an insignificant Levene's, ($F(4,277) = 1.600$, $p = .175$). Then a standard Dunnett's test results showed that categories two and five were both significantly different from the unprimed (Table 7), as the visual inspection of Figure 8 indicates.

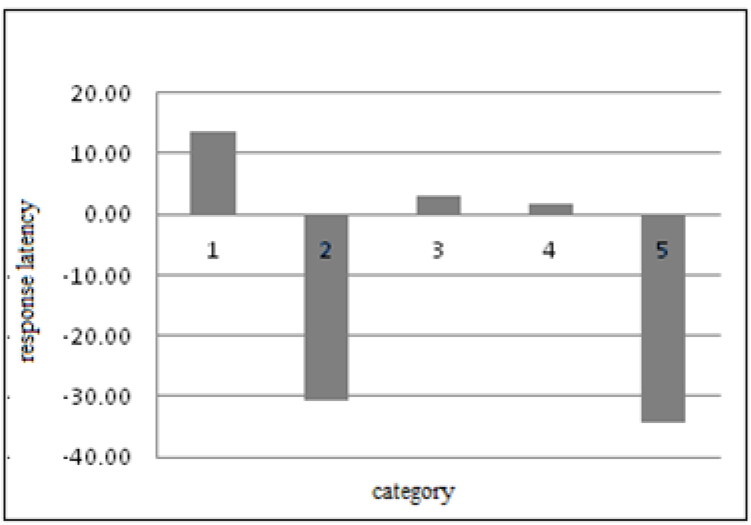

Figure 8. Gaussian category mean differences from Gaussian unprimed.
Unprimed is 0.00.

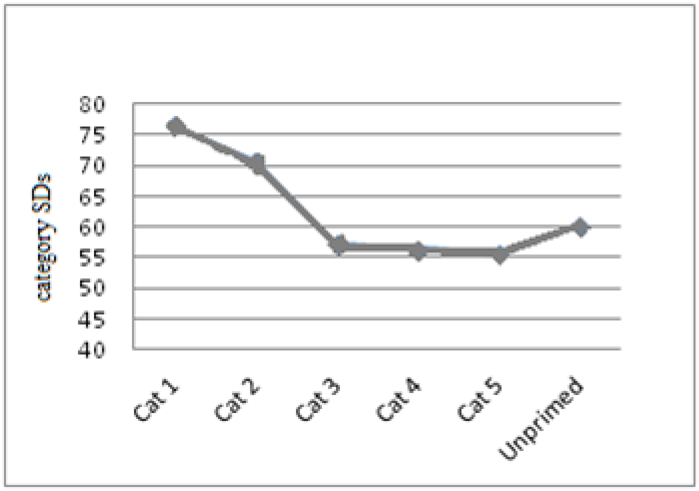

Figure 9. Comparison of Gaussian category standard deviations.

Table 6

Gaussian Category Standard Deviations

Category	SD
BREAD	76.458
FRUIT	70.631
HAIR	57.177
SCHOOL	56.416
TELEVISION	55.788
Unprimed	60.317

Table 7

Dunnett's Multiple Comparison of Gaussian Distributions, without Category One

		Mean Difference	Std. Error	Sig.	95% Confidence Interval Upper Bound
Unprimed	Category 2	-30.774*	11.445	0.014	-5.868
	Category 3	3.056	10.840	0.885	26.645
	Category 4	1.585	11.328	0.849	26.235
	Category 5	-34.250*	11.218	0.005	-9.839

*indicates significant difference ($p < .05$) between primed category and unprimed

Additional Correlations

Word frequency has been found to be related to priming effect (Scarborough, Cortese, & Scarborough, 1977; Andrews, 1992; Borowsky & Besner, 1993; Yap, Tse, & Balota, 2009), with words more frequently encountered in common experience producing less priming effect than less common words (see Nelson, McEvoy, and Schreiber, (2004) for a description of how word frequencies were determined). This was not the case in the present study. As Table 8 shows (see Appendix G), correlations between the raw data RLs from the LD task for each participant and individual word frequencies provided by Nelson, McEvoy, and Schreiber (2004) ranged from -0.23 to 0.33 ($M = -0.011$), with only two equal to or greater than the 0.250 required for the .05 level of significance for 60 degrees of freedom (Participant 5: $r = 0.287$, $p < .05$ and Participant 10: $r = 0.332$, $p < .05$. Gravetter & Wallnau, 2007; does not provide a value for 59 degrees of freedom, and none was found in further research).

Table 8

Correlations Between Word RLs from the Raw Data from the LD Task from Each Individual and Word Frequencies from Nelson et al. (see Appendix G)*

P6	-0.23
P3	-0.184
P2	-0.162
P4	-0.157
P8	-0.14
P12	-0.125
P13	-0.108
P17	-0.091
P20	-0.082
P19	-0.075
P15	-0.073
P14	-0.073
P18	-0.032
P1	0.032
P16	0.064
P7	0.165
P11	0.204
P9	0.219
P5	0.287
P10	0.332

The correlation between the word frequencies provided by Nelson, McEvoy, and Schreiber (2004) and the means of participant responses for each word was not significant (0.144, $p > 0.05$). The correlation between Gaussian category means and category word frequency means was also not significant (0.328, $p > .05$).

The correlation between age and mean RLs in the raw data was not significant ($r = -0.359$, $p > .05$). The correlation between education and age was also not significant, ($r = 0.436$, $p > .05$).

Previous research has also found that the stronger the associational strength between a primed word and an associated LD target word, the shorter the RL (Hines, Czerwinski, Sawyer, & Dwyer, 1986; Rosch, 1975). In the Nelson et al. database, associational strength is the probability that a word would be given in response to a presented word. For example, when 156 participants in the Nelson, McEvoy, and Schreiber (2004) study were presented with the word *bread*, 76 responded with *butter*. Therefore, 76/156 = 0.487 was the forward strength of the association between *bread* and *butter*. Similarly, the backward associational strength was the ratio of participants responding with *bread* when presented with the word *butter* (0.364). Generally in research, the stronger the associational strength between words, the faster the response. A relatively fast response produces a relatively short RL.

In the current research, correlations between the mean RLs from the LD target words and the forward and backward associational strengths provided in Nelson, McEvoy, and Schreiber (2004) were not significant (-0.162, $p > .05$) and 0.141, $p > .05$) respectively). This means that the usual finding, that words strongly associated with target words produce shorter RLs, did not hold true in the research reported here. This usual relationship might have been obscured by the strong exponential influence. Once the Gaussian components are extracted, the RLs of each word is not available in the data, so there was no way to gauge the influence of associational strength on RLs.

Summary

This research attempted to determine the mean implicit priming capacity in a group of 20 participants. An ANOVA between primed and unprimed RLs from the 20 sets of participant data analyzed was not significant; results showed no priming had occurred. However, when the Gaussian components of the ex-Gaussian primed and unprimed RL distributions from the grouped data were compared, and category one, which had the greatest variance, was removed, the one-way ANOVA showed that there was an overall significant difference. Dunnett's multiple comparisons test found that two categories (*fruit*, *television*) were significantly primed; that is, their priming was sufficient to significantly influence RLs in the LD task.

Results of the within-participants analysis showed a general increase in RLs in the primed categories, rather than the expected decrease that would indicate priming, and so the hypothesis that the mean number of significantly primed categories, from the within participants LD data, could not be tested, because no priming effect was found in the raw data.

Results also showed that raw data RLs were not significantly correlated with age or word frequency, or forward or backward strength reported in Nelson, McEvoy, and Schreiber (2004).

Chapter V follows. I will present and discuss conclusions drawn from this research.

Chapter V: Discussion

Introduction

The study reported here was an attempt to determine the number of unrelated categories of information that could be implicitly primed in individuals and remain primed for several minutes before being tested. It was expected that all five categories would be primed to some extent, and, based on previous research, that two to three would remain significantly primed until priming was measured a few minutes later.

The question asked by this research was, how many categories of information would remain primed strongly enough to influence participant behavior in a subsequent task? This research failed to provide an answer to this, but the grouped data analysis found that two categories remained primed sufficiently to influence the RLs during the LD task.

Interpretation of the Findings

The first task, the scrambled phrase task, presented participants with 10 words for each of five unrelated categories, to prime the categories. These words were not the focus of attention, but their meanings had to be accessed to complete the task problems. Accessing the meanings of the words also accessed the categories in memory to which they belong, and this facilitated access to other words presented in the lexical decision task, which have also been found to be associated with the primed categories, producing shorter response latencies for those words. Stated differently, during the scrambled phrases task, while the meanings of the individual words associated with the categories were accessed a single time each (semantic priming), the categories, defined in the scrambled phrase task, to which they belonged were accessed 10 times (category priming).

The second task in the experiment, the lexical decision (LD) task, attempted to measure the priming effect produced by the first task. Words that were related to the primed categories, words that were not related to the primed categories, and nonsense words (described in Chapter III) were randomly presented to participants, who were asked to decide as quickly as they could if the letter strings were words or not. The expectation was that words related to the primed categories would be responded to more quickly, producing shorter response latencies (RLs) than unprimed words or nonsense words. Nonsense words were presented to support the superficial purpose of the task.

Unfortunately, the originally planned analysis of individual LD data; finding the mean number of primed categories in a within-participant design, could not be conducted, because the raw data from the LD task showed that no priming had occurred for any participant; RLs for primed words were not shorted than those of unprimed words. A strong exponential influence was found (high-end outliers in Figure 4), and was assumed to have obscured any priming that might have occurred. The exponential components found in the individual data were hypothesized to have resulted from some additional variable's influence, such as inattention, or, hesitation caused by, possibly, participants *recognizing* words in the LD task; thinking that they had seen them in the scrambled phrase task, similar to O'Neill's (1954) example of a participant repeatedly guessing *camel* when *candle* was subliminally (taschistoscopically) presented and the word *thirsty* was continuously presented on the same screen. *Thirsty* apparently had primed a category involving desert, hot, dry, thirsty, etc., causing words associated with it, *camel* in the example here, to be primed; to come to mind easily; to be *recognized*. In the current study, a word associated with one of the primed categories might be *recognized* in a similar manner when it was presented in the LD task, causing a hesitation. The distortion in the individual data that this mis-recognition caused, might have composed the exponential components. Alternately, or additionally, the exponential distortion might have resulted from whatever produced the (nonsignificant) trend toward older participants showing faster RLs than younger participants (e.g., performance anxiety). Unfortunately, the distortion (from wherever it came) could not be separated from the individual data, due to there being too few data points; the number of data points from the LD task for each individual (10) was insufficient to identify the Gaussian components using the QMPE program. RLs should be distributed normally (randomly, independent of one another, producing normal curves; Gaussian distributions), and so the Gaussian components should show only the RL data (there was no way to determine if other Gaussian shaped influences (distributions) were present or substantially influential). The only way that a mean individual implicit category priming capacity could be determined was to first determine the number of categories primed in each participant, and then determine the mean. Because no participant data set showed a priming effect, no mean could be determined. This meant that the hypothesis for the individual data hypothesis could not be tested.

Exponential components were also found in the grouped data distributions of RLs (ordered by category), and were assumed to be from the same unknown source(s). To analyze the group data, to compare it to the grouped data results that Ray and Bly (2007) and Hines, Czerwinski, Sawyer, and Dwyer (1986) had reported, Gaussian components were extracted. Results of the grouped analysis would not be replications of the results reported by Ray and Bly (2007) and Hines, Czerwinski, Sawyer, and Dwyer (1986), because in those studies data was organized by participants, and the grouped analysis here was organized by categories, which was the only alternative, because, as was reported earlier here, the individual data consisted of only 10 data points, which was not sufficient to extract any Gaussian components that might be present. The analyzed data might, however, add to the results those researchers found, and so might add to the information accumulating about implicit category priming.

That analysis showed that the mean RLs of two of the primed categories remained significantly primed until tested in the LD task, after the category with the greatest variance was removed (Category one, *bread*). These results are not in conflict with those obtained by both Ray and Bly (2008) and Hines, Czerwinski, Sawyer, and Dwyer (1986). This result indicates that two of the primed categories (*fruit* and *television*) made a greater impact on participants than the other three categories *(school, hair,* and *bread*), for unknown reasons. Frequencies from the Nelson et al. study were used to select the priming and target words, and were expected to create roughly equally memorable primes and associated targets, but those frequencies apparently did not provide that equivalence.

These results, though, taken with Ray and Bly (2007) and Hines, Czerwinski, Sawyer, and Dwyer (1986) appear to indicate that, even though any finding would seem to be random, significant priming might occur in two to three categories, although if this is correct the reason for this is unclear. A replication study should be conducted to compare results.

Words more frequently encountered, using frequencies reported in Nelson, McEvoy, and Schreiber (2004), did not show the fastest RLs; these measures were not effective in creating roughly equivalent implicitly impressionable categories in the participant group. It would seem to indicate that the frequencies reported by Nelson et al. are not representative of the experiences of the participants involved in this present study. This also implies that this current study's findings are not generalizable and might be unique to this small group of Walden participants, who were from a variety of locations. Word frequencies reported in Nelson et al. (2004) were found by Kucera and Francis (1967) in their study of American English from Brown University.

Although not the focus of the current research, results from the present study replicate the findings reported by previous researchers (e.g., Casper, Rothermund, & Wentura, 2010; Graf, Shimamura, & Squire, 1985; Ray & Bly, 2007; Srull & Wyer, 1979) that implicit category priming produced by multiple primes can last longer than a few seconds, and can influence behavior in a following task.

The trend toward shorter RLs in the raw data for older participants might be an indication that the extraneous influence(s), which produced the stronger exponential values, was stronger in younger participants, possibly pointing toward, for instance, (as noted) performance anxiety, or something similar, as the cause, or a component of the cause.

Overall, the results of this research provided no direct measure of the number of unrelated categories a participant might be expected to be influenced by, which was the main goal of the research. The exponential influence obscured this information. The research was, however, able to measure the mean number of unrelated categories that might influence a group of participants, a few minutes after perceiving them. Results from future research will have to be used to determine if this value is reliable. The question remains unanswered what, if anything, this value, two categories, which, coincidently, was the same value as that predicted for implicit category priming capacity, represents.

Limitations of the Study

The main shortcoming of this research was that the RLs for the primed words were generally longer than the unprimed word RLs, exponential components in the data obscured the priming effect found in the Gaussian components. In addition, there were an insufficient number of words in the LD task to identify the Gaussian components in each individual's data, and this prevented the study's hypothesis from being tested directly.

Small sample size, 20 participants, was not a limitation for the grouped analysis, because there were sufficient numbers for the QMPE program to identify the Gaussian components in the five primed and the unprimed distributions. However, there were not, as noted, there were too few data points in the LD task for each individual.

Because the sample size was small, the generalizability of the results should be considered with caution. In addition, the sample here was relatively well educated, which will also likely limit the generalizability of the findings.

Finally, as was discussed earlier here (see discussion immediately before Table 3), there was a possibility that the presentation order of the categories could have influenced results; a high number of first or last presentations could have produced what research has termed primacy or recency effects. However, Table 3 shows that the two categories that showed a significant influence in the LD task, were not presented most often first or last. Rather, their strongest presentation positions were in the middle of the presentation order. FRUIT was most frequently presented first to participants and HAIR was presented most frequently last, did not produce significant priming in the LD task.

Recommendations

A replication study should be conducted that does not prime the categories so strongly, because this might have brought conscious awareness, attention, and explicit priming into the results, which might explain the strong exponential components in the distributions. The categories should also be primed all at the same time, rather than sequentially, so that there would be no possibility of primacy or recency effects, if a within-participant analysis is to be conducted. This might be done by presenting images of all five categories, distributed on a page, while having the participant locate some embedded image that has no relation to the five categories being primed. Some number of these problems could be presented, and then the implicitly primed categories could be measured using a LD task. In addition, a greater number of items per category per participant in the LD task should be used to provide sufficient numbers for reliable individual ANOVAs. A future study should also use a sample in which education is more varied, to better represent the U.S. population.

Implications

If the finding that implicit priming has a storage capacity of two in the grouped data is verified in replication studies, this might provide a gauge of the number that could be expected to be primed in a group of individuals. Educators might make use of this by constructing lessons that do not introduce more than, say, three variables at a time.

The results obtained in this research also indicate that participant pools that allow individuals from various locations to volunteer for studies do not provide appropriate samples for research involving word frequency data obtained from one local.

Once implicit category priming capacity is determined, that value could be a useful individual difference, in educational settings, and occupational placement. It is also needed to more completely understand priming.

Conclusion

Much of an individual's learning, their knowledge of the world, probably results from implicit processes. In school environments, for instance, where teachers put up posters and corkboard displays that students pass every day and barely pay attention to, and in social situations where much information is subtle and passes quickly. Understanding implicit priming and knowledge of the implicit priming capacity could aid in our understanding of how to most effectively provide peripheral learning tools, and possibly improve our understanding of social interactions.

If future research does not find that implicit priming capacity is due to some fixed physiological limitation, the capacity might be improved with practice. Lessons might be specifically designed to increase it and any skills found to be associated with its use, potentially having a broad impact on teaching and learning.

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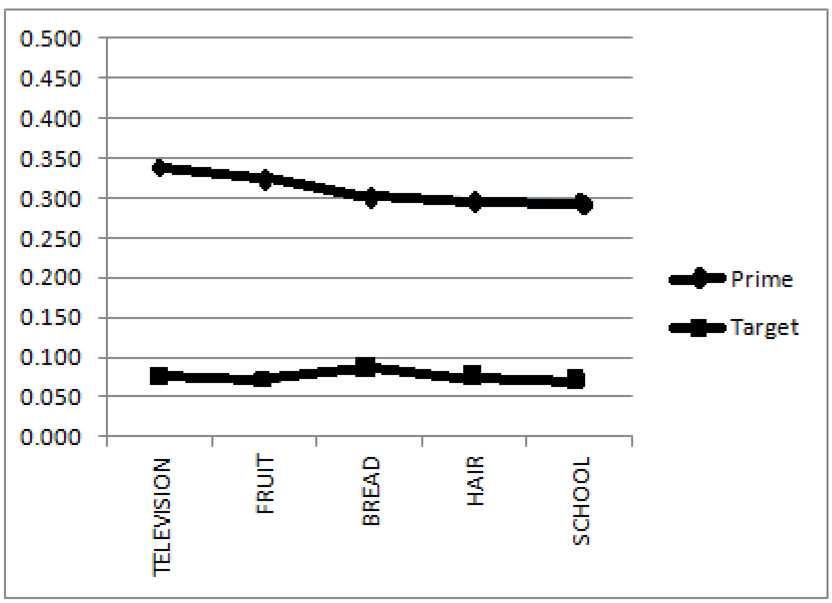
Appendix A: Categories, Priming, and Target Words - Statistics

	Prime		Target	
	AP		EP	
Categories	M	(SD)	M	(SD)
TELEVISION	0.337	(0.185)	0.077	(0.076)
FRUIT	0.325	(0.153)	0.072	(0.074)
BREAD	0.303	(0.180)	0.086	(0.151)
HAIR	0.297	(0.082)	0.075	(0.065)
SCHOOL	0.296	(0.074)	0.069	(0.032)



Appendix B: Categories, Priming, and Target Words

(AP = Afferent proportion from Nelson, McEvoy, and Schreiber (2004) data.)

Category	Primes	AP	Category	Primes	AP
BREAD	RYE	0.791	FRUIT	KIWI	0.709
	TOAST	0.364		CITRUS	0.426
	STALE	0.303		PEAR	0.347
	CRUMB	0.281		RASPBERRY	0.317
	CRUST	0.243		PLUM	0.299
	BUN	0.234		BERRY	0.298
	BAKER	0.230		PRODUCE	0.219
	TOASTER	0.197		STRAWBERRY	0.217
	MUFFIN	0.196		PEACH	0.206
	BISCUIT	0.194		BLACKBERRY	0.211
HAIR	STRAND	0.453	SCHOOL	CAMPUS	0.466
	SCALP	0.377		UNIVERSITY	0.338
	LICE	0.372		SEMESTER	0.322
	CONDITIONER	0.325		EDUCATION	0.315
	HEADBAND	0.270		PRINCIPAL	0.315
	DANDRUFF	0.268		EDUCATE	0.265
	MOUSSE	0.265		BACKPACK	0.259
	BALD	0.222		BOOKBAG	0.250
	CLIPPERS	0.221		CLASS	0.203
	BEARD	0.200		LEARNING	0.227
TELEVISION	CABLE	0.689			
	NETWORK	0.547			
	COMMERCIAL	0.414			
	ANTENNA	0.378			
	CHANNEL	0.372			
	MEDIA	0.318			
	PROGRAM	0.250			
	NEWS	0.110			
	SCREEN	0.154			
	ADVERTISEMENT	0.138			

Appendix B: Categories, Priming, and Target Words (cont.)

(EP = Efferent proportion from Nelson, McEvoy, and Schreiber, (2004) data.)

Category	Target	EP	Category	Target	EP
BREAD	BUTTER	0.487	FRUIT	APPLE	0.223
	DOUGH	0.058		ORANGE	0.174
	LOAF	0.051		BANANA	0.065
	FOOD	0.045		CAKE	0.06
	ROLL	0.032		SWEET	0.033
	SANDWICH	0.026		JUICE	0.027
	WHEAT	0.026		CUP	0.027
	EAT	0.026		CAN	0.016
	SLICE	0.019		GRAPE	0.016
HAIR	BRUSH	0.207	SCHOOL	WORK	0.128
	COMB	0.152		COLLEGE	0.112
	LONG	0.103		BOOK	0.071
	BROWN	0.043		BUS	0.071
	HEAD	0.043		LEARN	0.066
	BLONDE	0.033		STUDY	0.061
	CUT	0.033		STUDENT	0.041
	SHAMPOO	0.027		HOMEWORK	0.036
	HAT	0.022		TEACHER	0.036
TELEVISION	RADIO	0.221			
	SHOW	0.171			
	WATCH	0.121			
	SET	0.064			
	ENTERTAINMENT	0.036			
	STATION	0.021			
	VIDEO	0.021			
	BORING	0.021			
	PICTURE	0.021			

Note. AP = Afferent proportion from Nelson, McEvoy, and Schreiber (2004) data.

Appendix C: Scrambled Phrases

(all words are capitalized for presentation)

BREAD

RYE	or	white	over
best	had	on	TOAST
was	STALE	it	for
ate	a	CRUMB	the
trimmed	some	the	CRUST
BUN	hamburger	soft	the
by	BAKER	made	a
popped	TOASTER	up	down
the	sat	MUFFIN	buttered
BISCUIT	gravy	and	also

FRUIT

ate	KIWI	the	a
drink	CITRUS	the	she
tasty	PEAR	the	from
juice	drank	RASPBERRY	just
the	tasted	PLUM	for
blue	juicy	BERRY	a
PRODUCE	sold	also	the
preserves	jam	some	STRAWBERRY
fuzz	was	tickled	PEACH
BLACKBERRY	have	jelly	use

HAIR

STRAND	a	single	for
completely	BALD	almost	was
scrubbed	a	SCALP	her
clinging	LICE	removed	the
CONDITIONER	an	expensive	the
with	CLIPPERS	trimmed	just
full	a	done	BEARD
pretty	tied	the	HEADBAND
DANDRUFF	flakes	of	the
styled	the	MOUSSE	with

Appendix C: Scrambled Phrases (cont.)

(all words are capitalized for presentation)

SCHOOL

beautiful	a	CAMPUS	the
online	local	UNIVERSITY	the
ended	had	started	SEMESTER
his	EDUCATION	her	valued
strict	PRINCIPAL	friendly	a
EDUCATE	to	us	will
the	grabbed	BACKPACK	heavy
from	in	the	BOOKBAG
CLASS	the	for	late
easy	was	LEARNING	fun

TELEVISION

local	CABLE	new	service
the	were	local	NETWORK
watched	another	COMMERCIAL	the
use	ANTENNA	the	adjusted
CHANNEL	the	changed	same
popular	MEDIA	was	influence
favorite	their	PROGRAM	her
NEWS	on	the	watched
SCREEN	big	a	done
watched	another	ADVERTISEMENT	her

Appendix D: Unrelated and Nonwords Used in the LD Task

Nonwords	Unrelated Words
BOSER	CHOICE
TILOP	SUN
SHLEF	PATTERN
TAFAL	JUSTICE
OMOSE	POOR
VOBAE	OPERATION
SCAFE	SAYING
TOLBS	SEVEN
RUESH	DESIGN
SHAND	POOL
RUCET	
SMERG	
NAIRB	
MEASH	
GESPO	
CHESA	
SLEND	
KULLS	
NACLE	
FOROL	

Note: Nonwords from Borowsky and Bresner (1993)
Unrelated words from Nelson, McEvoy, and Schreiber (2004)

Appendix E: Returned Data Examples

Example of participant data returned for same individual as in the second table. Participant numbers are associated through a matrix.

5577	Date of Informed Consent Agreement:				Sun Feb 26 17:26:30 CST 2012			
5577	Completed Demographics:				Sun Feb 26 17:26:51 CST 2012			
5577	Gender:	1	Age:	61	YearsEd:	19	City:	Baltimore
	State:	Maryland	Country:		U.S.A.			
5577	System:	Windows		Explorer	8	1057	625	

Example of times returned when pages were completed (button was clicked on instruction page, and last item was completed in tasks):

PN	Activity	hr	min	sec (encrypted)
10647	LSI:	23	30	52
10647	FST:	23	42	43
10647	LLDI:	9	16	47
10647	FLDT:	9	18	10

LSI = Left scrambled task instructions
FST = Finished scrambled task
LLDI = Left lexical decision instructions
FLDT = Finished lexical decision task

Appendix E: Returned Data Examples (cont.)

Example of Scrambled Phrase response data:

PN	Cat	Phrase#	Phrase Entered	Response Latency (msec)
10647	P	0	was a molehill	5414
10647	P	0	sky was blue	5756
10647	P	0	birds were flying	6022
10647	2	1	ate the kiwi	5413
10647	2	2	drink the citrus	8595
10647	2	3	the tasty pear	7238
10647	2	4	drank raspberry juice	9922
10647	2	5	tasted the plum	6100
10647	2	6	a blue berry	7394
10647	2	7	sold the produce	6411
10647	2	8	some jam preserves	9688
10647	2	9	peach fuzz tickled	9719
10647	2	10	use blackberry jelly	10826

PN = participant number
Cat = Category, P = practice
P = practice trial

Appendix E: Returned Data Examples (cont.)

Example of Lexical Decision response data:

PN	Rel	Category	Letter-string	letter pressed	RL	correct-incorrect	
10647	U	Practice	HERE	w	577	C	
10647	U	Practice	MARCH	w	530	C	
10647	N	Practice	NACLE	w	553	I	
10647	R	FRUIT	APPLE	w	656	C	1
10647	R	BREAD	LOAF	w	577	C	
10647	R	TELEVISION	ENTERTAINMENT	w	577	C	
10647	U	UNRELATED	AGREEMENT	w	546	C	
10647	R	SCHOOL	HOMEWORK	w	562	C	
10647	R	SCHOOL	BUS	w	499	C	
10647	R	FRUIT	FRUIT	w	530	C	
10647	R	SCHOOL	BOOK	w	577	C	
10647	N	NONWORD	NAIRB	n	624	C	
10647	U	UNRELATED	REACH	w	592	C	
10647	R	TELEVISION	RADIO	w	640	C	

PN = participant number
Rel = relationship, R = related, U = unrelated, N = nonword
RL = response latency (milliseconds)
C = correct
I = incorrect

A number at the end of a response line, as in APPLE, indicates that a key other than *w* or *n* was initially pressed on that trial.

When that happens, the screen flashes green and the trial start time is reset and processing waits for the participant to make another selection. The number at the end of the response line is incremented each time that a key other than *w* or *n* is pressed in the same trial. The lexical decision instructions includes “The screen will flash green if you press a key other than 'w' or 'n,' and then the page will wait for you to press a 'w' or 'n'.”

Appendix F: Gaussian Distributions

The primed category and unprimed distributions were prepared starting at the mean provided by QMPE for each category, because this was the only RL value estimated for the Gaussian components provided by the program. Then, somewhat arbitrarily[13], 25 data points were created below this to the lowest value for each category in the trimmed data (the lowest RL was 331), then the same number of data points were created above the mean, giving a total of 51 data points for each category's created Gaussian. The separation between the data points was adjusted until the distribution SD was equal to the parameter provided by the QMPE software, to create the variance relationships. The created distributions span roughly -2 to 2SD, encompassing 99% of the RL range for each category. Both the means and SD of the created distributions are equal to the QMPE parameters to three decimal places. Figure 6 displays the created Gaussian distributions.

---

[13] The RLs in the raw data and the quantiled distributions provided by the QMPE program are combinations of the Gaussian and exponential components, therefore the number of data points that comprise the Gaussian components of the category distributions cannot be precisely known. Because 40 data points are the recommended minimum for the QMPE program, 51 data points (the mean plus 25 above and 25 below) were created.

Appendix G: Correlation between Individual LD RLs and Word Frequencies

Word Freq[1]	LD words	P1 RLs[2]
41	BREAD	556
27	BUTTER	534
13	DOUGH	671
61	EAT	665
147	FOOD	684
4	LOAF	652
35	ROLL	567
10	SANDWICH	560
13	SLICE	583
9	WHEAT	493
35	FRUIT	563
9	APPLE	537
4	BANANA	689
13	CAKE	614
61	CAN	705
45	CUP	572
3	GRAPE	617
11	JUICE	602
23	ORANGE	723
70	SWEET	556
148	HAIR	527
20	BLONDE	623
176	BROWN	501
44	BRUSH	609
6	COMB	661
192	CUT	633
56	HAT	581
424	HEAD	533
755	LONG	589
98	SHAMPOO	733

Word Freq[1]	LD words	P1 RLs[2]
492	SCHOOL	679
193	BOOK	803
34	BUS	680
267	COLLEGE	623
	HOMEWORK	578
84	LEARN	489
131	STUDENT	511
246	STUDY	693
80	TEACHER	511
760	WORK	640
50	TELEVISION	501
5	BORING	624
29	ENTERTAINMEN	677
162	PICTURE	607
120	RADIO	538
137	SET	657
287	SHOW	504
105	STATION	635
2	VIDEO	591
81	WATCH	651
113	CHOICE	621
114	DESIGN	620
114	JUSTICE	605
113	OPERATION	705
113	PATTERN	532
111	POOL	557
113	POOR	594
113	SAYING	630
113	SEVEN	540
112	SUN	548

[1] Nelson, McCovy, and Schreiber (2004)

[2] LD Raw Data RLS from Participant 1

Correlation between word frequencies and P1 RLs = 0.032