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The Role of Priming in Lexical Access and Speech Production

Meagan T. Farrell & Lise Abrams

University of Florida

Katherine K. White

Rhodes College

Please address correspondence to:

Lise Abrams, Ph.D.
Department of Psychology
University of Florida
P.O. Box 112250
Gainesville, FL 32611-2250

Phone: (352) 273-2149
Fax: (352) 392-7985
Email: abrams@ufl.edu

ABSTRACT

Human language function is inextricably linked to memory in that the comprehension and production of language requires access to linguistic structures stored at various levels of abstraction and complexity. The act of producing even a single word requires (at a minimum) the retrieval of its semantic, lexical, syntactic, and phonological/orthographic properties before articulation can occur. As with the retrieval of other structures and types of information stored in memory, the retrieval of language representations is shaped by the speaker's recent experiences and behaviors, some of which occur unconsciously via priming. This chapter will review extant research on priming within the domain of language production, specifically how the production of a single word is influenced by priming. Single-word production studies provide the bulk of empirical data used to inform models of language production, and priming research has been critical to our understanding of the levels of representation that are accessed by speakers during the course of word production. Describing a variety of methodologies, this chapter examines the different levels at which priming can influence production, particularly: 1) semantic activation, 2) lexical selection, and 3) phonological encoding. We will address several of the most important theoretical questions that have dominated the speech production literature and discuss how priming research has contributed to conclusions about the structures and processes engaged at the semantic, lexical, and phonological levels. A synthesis of findings from priming research will help to critically evaluate existing theoretical models of speech production and suggest directions for future research.

INTRODUCTION

The human brain is designed to identify patterns in the environment. This innate preference for consistency influences how new information is integrated with existing knowledge structures, and conversely, how experience guides future behaviors. Although we are often unaware of these influences, prior experience not only guides our overt actions and behaviors but also shapes how we think about and perceive the world. *Priming* refers to the phenomenon where one's response to a current stimulus is unconsciously affected by recent exposure to the same or a related stimulus, a mechanism presumed to reflect spreading activation among conceptually- or perceptually-similar structures stored in memory (e.g., Anderson, 1983; Balota & Lorch, 1986; Collins & Loftus, 1975; Neely, 1977; Posner & Snyder, 1975). Although early priming studies were designed to reveal the distinct organizational structures of episodic and semantic memory systems, more recently the priming effect has been extended beyond memory to a variety of psychological domains, including perception (e.g., Balcetis & Dunning, 2006; Michelon & Koenig, 2002), social behavior and stereotyping (e.g., Kawakami, Dovidio, & Dijksterhuis, 2003; Ledgerwood & Chaiken, 2007), and music cognition (e.g., Peretz, Radeau, & Arguin, 2004). The focus of this chapter is on priming within the domain of language, specifically the retrieval and production of individual words.

The application of various priming methodologies to the study of speech production has made substantial contributions to our understanding of the structures and processes engaged during single-word production. At a minimum, language researchers distinguish among three major domains of speech production: *semantics*, the linguistic representation of knowledge and meaning; *phonology*, the sound structure of language; and *syntax*, the rules and processes for the combinatorial potential of language. We begin this review with a description of the semantic, phonological, and syntactic properties of words and a brief presentation of the two most prominent types of speech production theories in terms of how these properties are accessed: *interactive* and *discrete*. We then provide a concise summary of common empirical methodologies used to investigate single-word production in order to facilitate the readers' understanding of the more complex tasks involving priming. Yet the primary goal of this chapter is to highlight the critical role that priming research has played in the construction of theoretical approaches to speech production. As such, the bulk of this review will focus on several of the most important research questions that underscore our understanding of speech production at the single-word level. We will describe how various priming paradigms have been used to develop preliminary answers to each of these questions and evaluate existing theoretical interpretations of empirical patterns. Unsurprisingly, some questions remain largely unanswered and demand substantial future inquiry before any solid conclusions can be drawn. Nonetheless, priming research has made great strides towards the development of more advanced models of the cognitive mechanisms that underlie successful word production and the conditions that encourage production failures.

Levels of Speech Production

Semantics

The semantic system is conceptualized as a vast, interconnected network of stored information, including person and place names, encyclopedic knowledge acquired through learning and experience, and the extensive repository of individual word items known as the "mental lexicon." Although the semantics of language refer to the symbolic manifestation of meaning achieved through words, the semantic system also contains concepts that do not correspond directly to specific lexical items. In the simplest of cases, such as the single-word production tasks used in laboratory studies (e.g., picture naming), an identified concept might correspond to a single entry in the lexicon. However, the discussion is complicated by the fact that although some concepts are aptly embodied by a single, specific word (e.g., a long literary narrative is called a *novel*), other single concepts require phrases to capture their meaning (e.g., a brief work of fiction is called a *short story*) or may have multiple word options depending on the context (e.g., a *novel* is typically just referred to as a *book*, unless the context requires the speaker to designate the type of book he/she is reading). Because of this imperfect relationship between a speaker's intention and his/her options stored in the lexicon, a dissociation between two levels of semantic representation becomes necessary: (1) the global idea or message that the speaker intends to express (i.e., *conceptual semantics*), and (2) the specific word or words that most accurately captures the message (i.e., *lexical semantics*).

Within the speech production literature, greater empirical and theoretical emphasis has been placed on describing the second, more concrete level of semantic preparation, *lexical selection*, which involves choosing the precise word or "lemma" used to convey a speaker's message. The average person's lexicon consists of 50,000 unique items (Levelt, 1999), thereby enabling the impressive flexibility and semantic potential of human language. While there is still some debate about how conceptual preparation and lexical selection processes interface, nearly all theoretical approaches acknowledge the functional and seemingly natural "rift" between semantics (word meaning) and phonology (word form; e.g., Levelt, Roelofs, & Meyer; 1999).

Phonology

The development of a language system requires pairing chunks of meaning with arbitrary symbols that, over time, become mutually understood by its users. Human language uses speech sounds to symbolize meaning, and the domain of speech production concerned with the retrieval and assembly of sound structures to produce words is called phonology. The symbols selected for a communication system have three primary requirements: arbitrariness, meaninglessness, and production (Gee, 1993). Language symbols are considered arbitrary in that the object or concept they are designated to represent is not based on any feature of the symbol itself. Further, language symbols are meaningless without an association to a referent; the combination of sounds in the word *table* lacked any meaning prior to being linked with the conceptual representation of a piece of furniture on which to place objects. Finally, the symbols need to be produced in some way in order to communicate meaning and transfer the information from one individual to another.

There is not a perfect one-to-one connection between a word's lexical representation and a corresponding phonological package. Instead, after lexical selection a speaker must retrieve smaller sublexical items (such as phonemes and syllables) from a phonological system that is shared by all words. The process of translating the representation of a word's meaning into sound is called *phonological encoding*, which starts with the construction of an abstract phonological frame and culminates with the preparation of motor plans to produce speech. A shared phonological system consisting of sublexical sound units as opposed to whole-word representations allows for the flexibility to produce novel "words" that are not stored in the lexicon and also explains the occasional speech error or "slip of the tongue".

Finally, articulatory programs that correspond to speech sounds are organized in precise ways and are drawn from a repository of phonemes, syllables, and other phonological segments that require complex coordination and rhythmic timing. Further, speech sounds are combined in systematic ways that are dependent on language-specific phonological rules that are acquired through language learning. Thus, the phonological system consists of both stored items (e.g., syllables, phonemes) as well as generative programs that constrain the combinatorial potential of the stored structures (e.g., Dell, 1986). However, the size of the phonological units that are accessed during production and the degree to which some phonological-level processes are similar across languages remain contested within the speech production literature (e.g., Ferrand, Segui, & Humphreys, 1997; MacKay, 1972; Schiller, 2000).

Syntax

Language expresses meaning not only through the relationship between lexical representations and phonological word forms but also through a word's relation to other words. In typical language use, single words are very rarely produced by themselves and instead occupy specific slots within strings of words, the placement of which is determined by the grammatical features of the word and the rules of a language (Bock & Griffin, 2000). The structural processes that guide the assembly of words and morphemes into meaningful sentences are referred to as syntax. In order to convey a message that is comprehensible to listeners, a speaker must combine words in a manner that respects the syntactic rules of a given language. Consider the string of words "*loves psychology professor lecture to the*" compared to "*the psychology professor loves to lecture.*" Although consisting of the same six words, only the latter string effectively expresses meaning because it obeys word order constraints imposed by English. In a sense, syntax acts as a "regulator", determining how to link the meaning of an individual word unit onto the more global message embodied in a phrase or sentence (Pinker & Jackendoff, 2005).

As with the domains of semantics and phonology, the syntactic domain includes both stored syntactic information as well as processes that direct the retrieval of syntactic features and their synchronization with the other components of language. Syntactic features of words include information such as grammatical category (e.g., noun, verb, adjective), the unique roles of function words (e.g., prepositions such as *of, at,* or *in,* pronouns such as *he* and *they,* and conjunctions such as *that* or *although*), and in some languages, information such as grammatical gender. Syntactic processes consist of regulatory rules including word order, inflection, and agreement (depending on the language).

Although syntactic theory is fairly well-developed at the sentence and discourse level, the role that syntax plays in the retrieval and production of single words remains vaguely defined. As a result, the representation of syntax in cognitive models of speech production is less concrete than the portrayal of semantic-, lexical-, and phonological-level processes. Many models suggest that syntactic features are inherently part of lexical selection (e.g., Dell, 1986; Garrett, 1988; Levelt et al., 1999; MacKay, 1987). Under these accounts, the lemma is basically a 'syntactized' version of the activated semantic concept (e.g., Levelt et al., 1999). Once a semantic concept is chosen for expression, a corresponding lemma is subsequently selected that provides direct access to all of the word's syntactic properties. As such, syntactic factors (such as grammatical class) help to determine which lemma is selected in a given sentential context but are also automatically retrieved even during single-word production. However, research investigating the influence of syntactic factors on single-word production has delivered highly inconsistent results, prompting the development of alternative theories that posit a separation of syntactic features from both the lexical/semantic and phonological word form (Caramazza, 1997), which allows for syntactic features to be selectively engaged during speech.

Discrete and Interactive Theories of Speech Production

Operating on the assumption that distinct semantic, lexical, and phonological levels of representation are accessed during word production, how does activation flow between these levels so that all necessary components of a word are retrieved in the correct order? Despite differences in terminology, most speech production theories agree that there are three primary “stages” of lexical access: the conceptual/semantic level, the lexical level, and the phonological form level (see Figures 1 and 2 for schematic depiction). However, there are two main points of dispute regarding the dynamics of spreading activation in the speech production network: the discreteness of stages (e.g., the extent to which stages overlap in time) and the directionality of connections (e.g., whether links between the conceptual, lexical, and phonological levels are unidirectional or bidirectional). Of particular interest among speech production researchers is the relationship between the lexical and phonological levels, and a variety of theories have been proposed to describe the degree of overlap and interactivity among these two stages. For sake of brevity, we describe two categories of speech production theories that exist on opposing ends of this continuum (although see Caramazza, 1997; Goldrick & Rapp, 2002; Rapp & Goldrick, 2006 for alternative theories). As depicted in Figure 1, *serial* or *discrete* models (e.g., Garrett, 1988; Levelt et al., 1999; Levelt et al., 1991) argue that speech production is a strictly serial process in that phonological activation can only begin after lexical selection has been completed, and only the phonological representations of selected lemmas become activated (see Morsella & Miozzo, 2002, for a description of serial models). Further, the connections between levels are one-directional, *feed-forward*, so that activity is prevented from feeding back from the phonological level to the lexical or semantic levels. *Interactive activation* models (represented in Figure 2) assume similar layers and forms of representations, but argue for *cascading* activation of phonology (e.g., Dell, 1986; MacKay, 1987): although phonological activation occurs only after lexical selection processes have begun, activation can sometimes "spill" into the phonological level before lexical selection has been completed. As a result, the phonological representations of both the selected lemma and other partially-activated (unselected) lemmas become simultaneously activated. Further, there is full interactivity among levels such that phonological activation can influence the activation levels of lemmas stored at the lexical level.

The model proposed by Levelt et al. (1999) is probably the most specified serial-discrete model of speech production (see Figure 1). Levelt and colleagues propose five distinct processing stages that occur prior to articulation, each of which produces a discernible “product” before advancing to the next stage: *conceptual preparation, lexical selection, morphological encoding, phonological encoding* (syllabification), and *phonetic encoding*. Conceptual preparation culminates with the selection of a specific *lexical concept* node, which is connected to other related nodes within the conceptual stratum. Once a lexical concept has been identified, a speaker can proceed with lexical selection, which involves the retrieval of the lexical concept’s corresponding *lemma* from the mental lexicon. The lemma node is linked with nodes representing the syntactic features of the word as well as other “diacritic” parameters when relevant, such as number, tense, or mood. Lemma selection marks the end of semantic-syntactically driven processes, and the speaker is now charged with phonological form retrieval and articulatory preparation. The first step of this process is the identification of the morphological makeup of the word. Production of the word “*reading”* requires the retrieval of its two *morphemes*, <read> and <ing>. Morpheme retrieval initiates the phonological encoding/syllabification process, where the *phonological word* is created. The phonological word acts as a frame for subsequent articulatory plans and possesses such characteristics as the number of syllables in the word, stress pattern, and other metrical features of the word. Finally, phonetic encoding produces a *phonetic gestural score,* which serves as a plan for the articulatory task to be performed.

Alternatively, according to Dell's (1986) interactive activation model, production begins with the creation of a tactic frame that embodies the speaker's intended message, designating category specific slots that need to be filled at each level of the production system. These slots are filled by words at the syntactic level (corresponding to lemma selection in Levelt et al.'s model), morphemes are selected at the morphological level (morphological encoding), and phonemes and features (e.g., manner of articulation, voicing, stops or fricatives, etc.) are selected at the phonological level (phonological and phonetic encoding). A competitive selection process occurs at each level, where the item with the highest level of activation within each level is chosen to fill the slot at each stage. Although there are clear parallels between the two models, Dell's model differs from Levelt et al.'s in a few critical ways. First, word meanings are represented in componential form as opposed to holistically so that semantic information about a word is distributed throughout multiple conceptual nodes as opposed to a single concept node dedicated to each lemma. Most importantly, Dell's model assumes that partially-activated lemmas can initiate phonological encoding before a single lemma is selected for production. Further, there is full interactivity among stages of processing so that connections between layers are both top-down and bottom-up connections. As such, activation at the phonological level may influence lexical selection processes.

A similarly conceived model is Node Structure Theory (NST; MacKay, 1987), a model of production that represents linguistic units as nodes in two cooperative, connectionist networks: the content network and the sequence network. The content network is composed of hierarchical nodes representing linguistic entities of descending size and levels of abstraction (conceptual nodes, lexical nodes, syllable nodes). The sequence network is responsible for controlling the order of activation of the content nodes, so that word, syllable, and segment selection occur in the correct order, and only one content node within a level becomes activated at a given time (Santiago, MacKay, Palma, & Rho, 2000). The content network consists of three major systems: the sentential/semantic system, the phonological system, and the muscle movement system. To a large extent, the processes that occur within each system parallel Levelt et al.'s stages of lexical access, with conceptual/semantic/syntactic processing culminating with lexical selection and phonological processing beginning with syllabification and ending with the retrieval of articulatory features. As with Dell's model, connections within each network are two-way in that activation is able to spread in both a top-down and bottom-up fashion. Unique to MacKay's model is the proposal of a separate sequencing system (conceptually similar to Dell's "slots-and-fillers" mechanism), where the content and sequence networks are united by lateral, one-way connections.

In sum, while serial-discrete and interactive activation models of speech production largely converge in their portrayal of the levels of representation that constitute a word and the processing stages that must be accomplished to produce it, they differ in the degree of distribution at the semantic level as well as the interaction of the lexical and phonological stages. Priming research has served as a critical tool for distinguishing between these two theoretical perspectives. However, priming as a research method is not a unitary construct; it has been implemented via diverse methodologies, which are discussed in detail below.

Methods for Studying Priming in Single-Word Production

Priming is a ubiquitous and automatic cognitive phenomenon whereby exposure to a stimulus or idea unconsciously influences the subsequent experience with a related stimulus or idea. A critical assumption of priming is that it reflects automatic spreading activation among stored structures that are related to one another on some dimension, and these relationships can be expressed in a variety of ways. Within the speech production domain, words can be related to one another at the semantic level (e.g., *dog* and *cat* are both animals, pets, and have fur), at the syntactic level (e.g., *dog* and *cat* are both nouns), and at the phonological level (e.g., *cat*, *hat, cap,* all share common phonemes). Knowledge of these relationships has allowed researchers to use priming to tap into different stages of the production system by inferring spreading activation among semantically-, syntactically-, and phonologically-related words. Prior to the application of this technique, early research on speech production used *observational* methods, which entailed the analysis of large samples of spontaneously-occurring speech (e.g., Fromkin, 1971; Garrett, 1975). The focus of many observational studies was on the occurrence of errors, broadly defined to include wrong sounds/words as well as dysfluencies such as hesitations and pauses. While this technique does not lend itself to experimentally-controlled priming, speech error analysis has served as a useful tool in characterizing the most common types of speech errors and the conditions that promote them, indirect indicators of spreading activation among related items in the speech production system. However, because errors occurred infrequently throughout these corpuses, conclusions from observational methods of speech production were relatively limited.

The development of various experimental methods gave researchers the flexibility to look both at errors and correctly-produced speech and also allowed specific variables to be manipulated prior to the production of speech. Although there are studies using physiological and neuroimaging methods to study single word production (e.g., Peramunage, Blumstein, Myers, Goldrick, & Baese-Berk, 2011; Schiller, 2006; Schuhmann, Schiller, Goebel, & Sack, 2009), this chapter focuses specifically on behavioral research methods, as they encompass the majority of studies that have been conducted to date, particularly in the field of priming. Although many studies opt to manipulate characteristics of the to-be-produced target, one of the most informative variables to manipulate is the relationship between a target stimulus and another related stimulus referred to as a“prime”. A prime is generally presented close in time to the target, and any influence of the prime on the production of the target, such as increasing or decreasing the likelihood of a speech error or the time needed to begin production, is called a *priming effect*. However, not all primes produce positive outcomes. When priming speeds the correct production of a target, it is referred to as a *facilitaiton effect*, whereas priming that delays the production of a target or induces a speech error is called an *interference* effect. Many tasks have used a priming methodology to investigate single-word production, and four of the most commonly-used tasks are described briefly below: (1) word naming, (2) picture naming, (3) tip-of-the-tongue (TOT) states, and (4) error elicitation.

Word naming is a relatively simple task where a target word is visually presented, and a person's task is to produce that word aloud. The priming manipulation comes into play before the target is shown such that some other word or sometimes a picture (the prime) is presented first and its influence on the target's production is measured (e.g., Bajo,1988; Balota & Lorch, 1986; Ferrand, Segui, & Grainger, 1996; Ferrand et al., 1997; Forster & Davis, 1991; Hines, Czerwinski, Sawyer & Dwyer, 1986; Hutchison, 2003; Kinoshita, 2000; Lucas, 2000; Schiller, 1999; 2000; 2004; Van den Bussche, Van den Noortgate, & Reynvoet, 2009). Various methods have been used to manipulate priming, including the relationship between prime and target, the modality of presentation (either visual or auditory), as well as the length of time between the prime's onset and the target's onset (stimulus onset asynchrony, or SOA), each desgined to tap into different aspects of word production and language processing. The most common dependent measure reported in word naming is mean naming latency, which reflects the time between the onset of the target and the onset of the utterance. Although some studies also report accuracy in word naming, defined as percentage of trials where the particpant produced the correct target word without a speech error, accuracy is generally very high, so it is not a discriminating measure of naming performance. Priming's influence on word naming can also be measured in other ways via the presentation of ambiguous or degraded target stimuli. For example, particpants may be asked to name homographs (words like *record* that have multiple pronunciations), and researchers can measure the likelihood of a particular pronunciation as a function of the prime word (e.g., Melinger & Koenig, 2007). It is also worth noting that priming effects are not necessarily a result of conscious processing of the prime. Some researchers have used a technique called *masked priming*, which involves first presenting a "mask" such as a string of # signs, followed by a very brief presentation of the prime (e.g., 50 ms), which then is replaced by the target. The logic of masking is to process the prime without conscious awareness so that its effect on production of the target is implicit and not linked to strategic processing.

In contrast to word naming, *picture naming* requires people to produce the name of target pictures that are presented (see Glaser, 1992, for a review). Primes used in picture naming tasks have consisted of various materials, such as words presented visually or auditorily, words produced in response to definitions, or pictures. Similar to word naming, picture naming studies manipulate the relationship between the prime and the target picture to assess the conditions that either facilitate or interfere with naming the picture, reporting naming times and sometimes accuracy or percentage of errors. For example, studies have manipulated whether the prime overlaps semantically (in meaning) or phonologically (in sound) with the target. Picture naming and word naming studies also have manipulated SOA. The most common SOA for tapping into lexical processes is 0 ms (which is simultaneous presentation of the target and prime), but SOAs can also be negative (the prime appears up to 1000 ms before the target) or positive, where the prime is actually presented after the target. Timing of the prime's onset is a critical determinant of its influence on naming a target, which provides significant insight into the time course of word production.

A third method for priming single-word production involves *tip-of-the-tongue* or *TOT states*. A TOT is a temporary word retrieval failure, marked by an inability to produce a word that one knows (e.g., Brown & McNeill, 1966). TOTs can be induced in the laboratory by asking participants to name pictures of well-known people or to give answers to definition-like questions. Priming has been used to study two aspects of the TOT experience: TOT incidence (how often do TOTs occur?) and TOT resolution (once having a TOT, how often is it resolved?). With respect to TOT incidence, prime words can reduce the occurrence of TOTs when a prime is presented before the target picture/question (e.g., James & Burke, 2000; Rastle & Burke, 1996). Similarly, primes can increase TOT resolution, i.e., facilitate retrieval of the target, when the prime is presented during a TOT (e.g., Abrams, White, & Eitel, 2003; James & Burke, 2000; White & Abrams, 2002). It is also important to note that priming of TOT states assumes an implicit influence where people are unaware of the relationship between the prime and the target and are therefore not using the prime strategically to guide their retrieval of the target. Some TOT studies have used a "cueing" methodology, where participants are told that the word may or may not help them to retrieve the target (e.g., Meyer & Bock, 1992), which in turn could lead to more directed searches for the target. Cueing methods reflect cognitive processes different from those that occur with priming and therefore will not be reviewed in this chapter.

Error elicitation tasks are designed to encourage speech production errors or ‘slips of the tongue’ through the priming of specific types of whole-word substitutions (e.g., *nun* for *priest*) or priming various types of speech sound errors (e.g., *barn door* for *darn bore*). While a handful of studies prime speech errors using single-word production techniques such as picture naming (e.g., Ferriera & Griffin, 2003), the most common error elicitation tasks differ from the previously-described approaches in several ways. First, they are not technically single-word production tasks because often multiple words (phrases or sentences) are produced. Second, these tasks do not present a specific prime but instead create circumstances within the target words themselves that increase the likelihood of making speech errors. One such technique is the SLIP paradigm (Baars, Motley, & MacKay, 1975; Motley, 1980), where people silently read successive pairs of words in which each pair has the same initial sounds (e.g., *ball-doze*, *bash-door*, *bean-deck*). People are then cued with an auditory signal to say aloud the target pair, whose initial sounds have been swapped (e.g., *darn-bore*). People are more likely to produce a speech error like *barn-door* when saying the target pair because of priming that specific pattern of word onset sounds, compared to target pairs that had not been preceded by pairs with the same onsets. Another error elicitation task involves the production of a sequence of words that are typically alliterative, such as tongue twisters (e.g., Dell & Repka, 1992; Sevald & Dell, 1994), which require the repetition of closely related phonological features whose similarity makes them prone to error when producing them quickly. When producing "a bucket of blue bug's blood", people make systematic speech errors such as anticipations and perseverations, producing sounds earlier or later than intended, respectively. The similarity of sounds and their proximity to one another in the phonological system causes activation to spread between them, therefore priming certain sounds to be produced more frequently than is required.

Results from priming used in word naming, picture naming, TOT, and speech error studies have formed the empirical backbone for most existing models of speech production. The true brilliance in these designs has been the development of key methdological variations that enable researchers to tap into distinct stages of lexical access and speech production. The application of various priming techniques to basic single-word production tasks has perhaps served as the most valuable agent in guiding our understanding about the underlying structures and stages of processing. By reviewing extant evidence from these diverse methodologies, we will attempt to address some of the most pressing questions regarding the dynamics of word production at the semantic activation, lexical selection, and phonological encoding levels, specifically: (1) how are semantic relationships expressed in the lexicon?, (2) how do semantic relations infleunce lexical selection?, (3) are syntactic featuers accessed during lexical selection?, (4) what causes word retrieval failures?, and (5) is there bidirectional interactivity between lexical selection and phonological encoding?

Semantic Activation

A variety of methodologies have demonstrated semantic priming effects on speech production, where the production of a "target" (e.g., *needle*) is influenced by prior exposure to a semantically-related "prime" (e.g., *thread*). In typical primed naming paradigms, participants are presented a prime (word or picture) and a target (word or picture) and are asked to ignore the prime and name the target aloud. Prime-target pairs are either semantically-related (e.g., *lion-tiger*) or unrelated (*lamp-tiger*), and a significant priming effect is expressed by different response latencies in the semantic condition relative to the unrelated condition. However, one of the most complex problems confronted by semantic priming research is trying to dissociate whether semantic priming effects are due to "pure semantic" relations between words (e.g., words that share common conceptual or perceptual features such as *lion-tiger*, or *lion-animal*), or are instead produced by associative relations between words (e.g., words that have a high tendency to co-occur in language but are not necessarily linked at the semantic level, e.g., *dog-*

bone). Further, whether the influence of semantically-related primes is facilitative versus inhibitory differs as a function of task type, which is interpreted as evidence for effects of semantic priming at different stages in the speech production process (semantic activation and lexical selection, respectively). Therefore, the primary goals of this section are to address whether semantic priming effects are driven by semantic or associative relationships in the lexicon and to determine when semantic relationships facilitate or inhibit lexical selection.

Most models of language processing agree that words and their meanings are expressed as two separate, though interconnected layers within the semantic system: individual word items are stored as lemmas in the mental lexicon (*lexical semantics*), and the concepts that lemmas symbolize are represented at a more abstract level in semantic memory (*conceptual semantics*; e.g., Dell, 1986; Levelt et al., 1999; MacKay, 1987; also see Hutchison, 2003; Lucas, 2000, for reviews of models of semantic memory). The two domains are united by direct connections between concepts and corresponding lemmas, and spreading activation among these connections allows the activation of one word to influence the activation levels of other semantically-related words. Therefore, a speakers' ability to quickly select a contextually-appropriate word from the thousands of word options in the mental lexicon is dependent on the organization of these two systems and the links that connect them. In Collins and Loftus' (1975) original model of semantic memory, concepts are connected as strongly to words in the lexical system as they are to related concepts in the semantic system.

However, not all perspectives conceptualize semantic relationships the same way. Historically, speech production researchers have shied away from constructing detailed models of conceptual semantics, although semantic priming effects have been explained by several disparate theories of semantic memory. According to *localist network models* (e.g., Anderson, 1983; Collins & Loftus, 1975), semantic priming occurs when activation spreads between whole units (nodes); nodes in the conceptual system represent whole concepts (e.g., the concept of a *table*), and nodes in the lexical system represent words (e.g., the lemma for *table*; see Hutchison, 2003, for review of connectionist models). Connections between concepts are formed through learned associations over time. As a result, the two words *needle* and *thread*, which do not possess similar meanings or share semantic features, would still be semantically related at the conceptual level. In contrast, *distributed models* do not represent words via holistic units. Instead, each word is expressed as a unique constellation of sets of features (e.g., Plaut & Booth, 2000; see also Pulvermüller, 1999, for a similar idea about the cortical representation of words). Priming occurs when two words have common semantic features so that the activation of the feature results in shared activation between the networks representing each word. Finally, in *lexical co-occurrence models*, relationships are formed between words when they are repeatedly used in the same or similar contexts during language use (e.g., Burgess, 1998; Landauer & Dumais, 1997). For example, latent semantic analysis, LSA (Landauer & Dumais, 1997) is based on large-scale corpus of text input where semantic relationships are measured by the global co-occurrence of words in the corpus.

Speech production theories are similarly fractionized by their portrayal of the conceptual semantic system and its relation to the lexical level. The interactive models of Dell (1986) and MacKay (1987), though quite consistent with some aspects of early semantic memory models in terms of spreading activation between the conceptual and lexical levels, also contain some elements of the distributed network models, such that the activation of a lemma (lexical selection) occurs as a result of converging semantic features. The semantic representation of a word is the set of semantic features that are activated during the course of production (see Figure

2). In contrast, the model proposed by Levelt et al. (1999) is more similar to the original localist network models, where the conceptual stratum consists of lexical concept nodes (that represent the entire concept to be expressed), which are connected to other related lexical concepts and their corresponding lemmas in the lexical stratum (refer to Figure 1). Connections between lexical concepts are not based on distributed semantic feature overlap but on lexical association and meaning similarity. Further, there is a one-to-one connection between a single lexical concept node and its corresponding lemma. To summarize the theories, Levelt and colleagues propose a holistic approach to conceptual semantics while the other models allow for decomposed semantic features, although the two models converge in their assumption of free-form spreading activation between the conceptual and lexical domains. Overall, while it is accepted that semantically-related words influence the activation levels of one another, the processes that create these connections are less concrete.

How are semantic relationships expressed in the lexicon?

Much of the early research on semantic priming in speech production was based on simple word naming or pronunciation tasks (e.g., Bajo, 1988; Balota & Lorch, 1986; Hines et al., 1986; Hutchison, 2003; Lucas, 2000; Van den Busscheet et al., 2009). While the majority of word naming studies report significant semantic facilitation, the degree of facilitation varies wildly between studies (Hutchison, 2003; Lucas, 2000), due to critical methodological tweaks aimed at tapping into different aspects of semantic processing. Two of the most important objectives are to more precisely define what is meant by words having a “semantic relationship” and to reveal the extent to which semantic priming effects reflect automatic spreading activation or conscious strategy.

Isolating the source of semantic facilitation in word naming has been a challenging undertaking, primarily because it is difficult to select prime-target pairs that are exclusively semantically-related or only associatively-related (Hutchison, 2003; Lucas, 2000). Strongly associated words (*dog-cat*) typically form associations because they are also related at the semantic level. Further, there is no established method for measuring the strength of association or semantic relation between words. Despite these challenges, a number of different types of prime-target relations have been used to investigate semantic versus associative priming, including synonyms (*afraid-scared*), antonyms (*hot-cold*), category members (*cherry-apple*), superordinate-subordinate pairs (*animal-dog*), script relations (*restaurant-waiter*), functional relations (*broom-sweep*), associated phrases (*spider-web*), and words that share a single perceptual feature (*snake-river*). While it is not always obvious which of these relationships are associative versus semantic in nature, there is some agreement that synonyms, antonyms, and category coordinates fall into the semantic feature category (e.g., Harley & MacAndrew, 2001).

Although variations in prime-target relationships have contributed to a better understanding of the types of semantic relations that are encoded in the lexicon, achieving a general consensus on the source of semantic facilitation has been limited by researchers' use of different operational definitions. Some recent efforts have been made to consolidate this disparate literature. Lucas (2000) conducted a large meta-analysis on semantic priming effects on lexical decision (a visual recognition task where the participant is asked to make a two-choice judgment on whether a target is a word or not) and word naming, including 26 studies that used "pure semantic" prime-target pairs that had zero or very minimal associative relationship. She concluded that pure semantic priming does occur in the absence of association. Although she found no evidence for pure associative priming (prime-target pairs that are associated but not semantically-related), there may be an associative "boost" such that words that are both semantically-related and associated show the largest priming effects. It is worth noting that while Lucas collapsed across naming and lexical decision in the overall analyses, post-hoc tests revealed smaller but significant semantic priming effects on naming. Potential reasons for the reduction in semantic priming for word naming compared to lexical decision are discussed later. Conversely, Hutchison's (2003) subsequent meta-analysis found evidence for both associative and semantic priming. Conclusive evidence for associative priming comes from so-called "mediated" semantic priming, where prime-target pairs (*lion-stripes*) are not directly associated with another but have a common concept to which they are both associated (*tiger*). For example, Balota and Lorch (1986) found that pronunciation latencies were faster when targets were paired with a mediated concept relative to a neutral or unrelated prime condition. Because *lion* and *stripes* do not share a single semantic feature, at least some of the semantic priming effect must be due to associative links among words.

Critically, most semantic priming methods in speech production employ tasks that do not require explicit access to word meanings, suggesting that semantic features are automatically engaged during word retrieval, at least to some extent. In order to rule out the possibility that semantic priming effects are due to conscious strategies used by the participants during the task, a number of studies have attempted to reduce the amount of attention placed on the prime word (see Lucas, 2000; Van den Bussche et al., 2009 for reviews). Compared to lexical decision, speeded naming is less susceptible to the use of strategic processes because the participant is not asked to make a binary response (Balota & Lorch, 1986). However, if participants detect any relationship between primes and targets, even naming is vulnerable to expectancy bias so efforts have been made to reduce the participants' opportunity to consciously alter their response patterns as a function of the stimuli. For example, priming studies reduce the RP (the ratio of related trials to unrelated trials) to prevent the participant from anticipating primes, minimize the SOA to reduce the time available to process the prime, or make use of a masking procedure to make the prime less visible to the participant. For the most part, significant semantic priming persists in these conditions, suggesting that priming effects reflect automatic spreading activation among related concepts and words as opposed to the participants' use of anticipatory strategies (e.g., Lucas, 2000; but see Bajo, 1988).

In summary, the literature on semantic priming of word naming has investigated a number of different semantic relations between words. While useful in determining the types of connections that are most critical to word retrieval, the diverse methodologies have made it difficult to isolate the precise locus of semantic facilitation. At this point, it appears that connections between words are formed at the level of conceptual semantics both through shared semantic features and lexical co-occurrence or association. As such, the results of word naming studies are unable to provide unequivocal evidence in support of discrete versus interactive model's depictions of the conceptual semantic system.

It is worth noting that semantic priming effects in word naming studies are relatively modest, which may be due to the nature of the task. Because the orthographic form of the target is provided, word naming is a task that at best minimally engages semantic word features and may be accomplished without accessing a word's semantic representation at all (Vitkovitch, Copper-Pye, & Leadbetter, 2006). In support of this assumption, facilitation from semantically-related primes (both picture and word primes) during word naming disappear when opportunities for semantic activation of targets were minimized (see Bajo, 1988). To gain a more comprehensive idea about the organization of the conceptual semantic system and its influence on lexical processes, it may be necessary to employ tasks that are better able to engage semantic activation and lexical selection, such as picture naming. Indeed, picture naming and picture-word interference tasks are likely to show more robust semantic priming effects because they require speakers to access every level of the target's representation (from conceptual semantics through phonology).

How do semantic relations influence lexical selection?

The key difference that separates picture naming from word naming is the importance of lexical selection during picture naming, where a specific lemma is selected for production. When a participant sees the visual image of a depicted object (e.g., *lion*), the visual percept activates the concept of *lion*, which in turns sends activation to its corresponding lemma. At the same time, activation is spreading to other related concepts (*tiger*, *bear, zoo*) and their corresponding lemmas, such that multiple lemmas may be activated simultaneously. Because the speaker has a number of options to select from for production, most models agree that lexical selection involves a period of competition among activated lemmas (e.g., Dell, 1986; Levelt et al., 1999; MacKay, 1987; but see Mahon, Costa, Peterson, Vargas, & Caramazza, 2007). During picture naming, the target lemma will receive the most top-down activation from the semantic level so it will be the first lemma to receive enough activation to reach threshold and be selected for production. However, the time required for the target to be selected is sensitive to activation of competitors. As a result, lexical selection is delayed as a function of the number of activated competitors and the relative activation levels of competitors (e.g., Abdel Rahman & Melinger, 2007; Miozzo & Caramazza, 2003).

In contrast to word naming, the influence of a semantically-related "prime" word is typically inhibitory within the context of picture naming, such that semantically-related primes increase naming latencies relative to unrelated words. An extensive collection of studies have demonstrated robust interference from semantically-related competitors during picture naming (e.g., Abdel Rahman & Melinger, 2007; Damian, Vigliocco, & Levelt, 2001; Kroll & Stewart; 1994; Sailor, Brooks, Bruening, Seiger-Gardener, & Guterman, 2008; Schriefers, Meyer, & Levelt, 1990; Starreveld & La Heij, 1995, 1996). Two different experimental paradigms are commonly employed: picture-word interference (PWI) and blocking. In the picture-word interference task, target pictures (e.g., *lion*) are named more slowly when they are presented with a semantically-related distractor (e.g., *tiger*) relative to an unrelated distractor word (e.g., *table*) (Cutting & Ferreira, 1999; Sailor et al., 2008; Schriefers et al., 1990; Starreveld & La Heij, 1995, 1996). A parallel result is found in the blocking paradigm, where pictures are presented in blocks of semantically homogenous items (all animals) or blocks of random, unrelated items. During this task, naming times are slower when pictures are named in blocks of semantically-related items compared to the blocks consisting of random items (e.g., Abdel Rahman & Melinger, 2007; Damian et al., 2001; Kroll & Stewart; 1994).

Both of these patterns of results are interpreted as evidence for competition at lexical selection among semantically-related words. In PWI, the presentation of a semantically-related word initiates direct competition between the target's lemma and the distractor's lemma (or any other lemmas activated by the distractor). The set of semantic features (e.g., Dell, 1986; MacKay, 1987) or lexical concepts (e.g., Levelt et al., 1999) shared between a semantically-related distractor and the target allows the distractor to become a viable candidate for production, and as a result, it takes longer for the target's lemma to be selected. Similarly, in the blocking procedure, the cumulative activation of members of a semantic cohort (e.g., animals) causes spreading activation among related items, thereby inducing competition at the lemma level.

The degree of competition from semantically-related competitors in the PWI paradigm is highly reliant on both the SOA and the semantic relationship that exists between a target and prime. In regards to the first issue, semantic interference effects are typically only found at negative SOAs (e.g., -200 ms), or when the prime and target are presented simultaneously (0 ms), although interference has occasionally been reported at very brief positive SOAs (see Sailor et al., 2008, for a review). This "early" semantic interference effect is taken as evidence that the activation of semantically-related words induces competition at lexical selection as opposed to delaying processes at later, post-lexical stages such as phonological encoding. However, the lexical selection by competition interpretation for the semantic interference effect has been challenged by studies showing that semantic interference is limited to categorically-related distractors (*ant-bee*). Associatively-linked distractors (e.g., *honey* for the target *bee*) exhibit no effect, or even lead to facilitation, on picture naming latencies (Abdel Rahman & Melinger, 2007; Costa, Alario, & Caramazza, 2005; Mahon et al., 2007; Sailor et al., 2008). Existing models of speech production do not provide clear a priori predictions for semantic competition exclusive to category coordinates, leading some to argue for a non-lexical locus of the semantic interference effect and a rejection of the lexical selection by competition hypothesis (e.g., Costa et al., 2005; Mahon et al., 2007). For example, after finding semantic facilitation for distractors bearing a part-whole relationship to the target (e.g., *bumper-car*) but interference from within-category distractors (*truck-car*), Costa et al. suggested that the semantic interference effect may occur as a function of the time needed to select a semantic concept for lexicalization, a process that takes longer when multiple concepts are activated and are all similarly relevant for the task at hand (see also Mahon et al., 2007, for a similar idea). In this framework, associative distractors would not cause interference because categorical information (e.g., the target is a vehicle) can be accessed early in the process, so non-categorical distractors (*bumper*) would be immediately identified as irrelevant, therefore allowing the target's concept to be selected without a delay.

However, Abdel Rahman and Melinger (2007) provide an alternative explanation for the categorical interference/associative facilitation paradox that does not require a dismissal of the lexical selection by competition hypothesis. Specifically, they argue that categorical distractors are inherently more similar to the target than associates (and as such, more competitive with the target), both in terms of the number of shared semantic features and a common "category node" at the conceptual level. Once a within-category distractor is presented (e.g., *truck* for *car*) it spreads activation to all concepts within that category and/or all items that share semantic features, resulting in the activation of a cohort of lemmas, all of whom become viable competitors with the target. In contrast, an associatively-related distractor (*honey* for *bee*) does not share a semantic category node, nor does it have many semantic features in common, so there is no convergence of activation between the target and distractor, and thus no activation of a competitive cohort of lemmas. In support of this explanation, Abdel Rahman and Melinger "created" a shared semantic context between associate distractors and targets by using a blocking procedure. For example, during one experimental block, all target pictures and their associative distractors (e.g., *harpoon-fish*) were from the same semantic context (e.g., the sea). In this way, associated words were presumed to form a temporary semantic context node, akin to the category node for categorically-related words. As predicted, when associative distractor-target pairs were presented in blocks of homogenous semantic contexts, semantic interference emerged. Overall, it does not appear necessary to discard the lexical selection by competition assumption inherent to most models of speech production, including both discrete and interactive models.

Further, both types of theories can accommodate the dissociation between associates and category coordinate distractors by allowing for increased lexical competition when distractors activate more alternate lemmas, either due to spreading activation among items in a single category node in the conceptual system (e.g., Levelt et al., 1999) or among items with shared semantic features (Dell, 1986; MacKay, 1987).

Studies investigating naturally-occurring (Harley & MacAndrew, 2001) and experimentally-induced speech errors also suggest that semantic priming influences lexical selection, or in this case, lexical “mis-selection” (Ferreira & Griffin, 2003). For example, Ferreira and Griffin (2003) asked participants to name target pictures (e.g., *priest*) after first reading cloze sentences that primed a semantic competitor (e.g., “The woman went to the convent to become a _________”) or an unrelated word (e.g., “He lit the candle with just one ________”). When attempting to name the target picture (*priest*), participants were more likely to mistakenly produce the competitor (*nun*) than they were to produce the unrelated word (*match*). These results confirm the importance of converging semantic activation on lexical competition and selection. A review of speech error corpora also reveals a clear semantic intrusion effect on the proportion of speech errors: when speakers make whole-word substitution errors during the course of natural speech, the substituted words have a tendency to be semantically-related to the intended word at well-above chances levels (e.g., Dell & O’Seaghda; 1992; Harley, 1984; Harley & MacAndrew, 2001). Although this type of research does not reflect semantic priming per se, it again reveals how the activation of a to-be-produced concept results in spreading activation to other related concepts and may ultimately lead to the activation of alternate lemmas. Semantic substitution errors are thought to occur at some point between the formulation of a conceptual message and the retrieval of the phonological properties of a word, namely during lexical selection (Harley & MacAndrew, 2001).

The types of intrusion words that are produced may help to shed light on the distinct origins of shared-feature semantic priming/interference versus associative priming. Harley and MacAndrew (2001) compiled speech error data from a number of corpora collected throughout several years in order to characterize the features that influence word substitution errors. Although the authors addressed semantic intrusion errors (*toad* for *frog*), phonological intrusion errors (*toad* for *toast*), and mixed errors (words sharing both semantic and phonological features, *toad* for *turtle*), only results relevant to semantic errors will be addressed here. Importantly, among semantic intrusions, 82% were shared-feature substitutes, while associatively-related words were produced on only 18% of semantic errors. Most common were antonym substitutions, suggesting that although two words may have opposing meanings, their overlapping semantic features nonetheless allow for powerful semantic interconnectedness. These findings suggest that semantically-related words (those sharing common features) are more likely to influence lexical selection processes than associatively-related words. It is also interesting to note that among shared-feature substitution errors, the substituted words tended to be more imageable than the target words. The imageability effect did not emerge for substitutions involving associatively related words, again suggesting a differential locus for words related by associate as opposed to semantic features.

What we know about semantic activation

Words form semantic relationships with one another due to both semantic feature overlap and lexical association. These two factors conjointly allow semantically-similar words to influence the activation levels of one another, thereby directing lexical selection processes. What is less clear is at what level these two types of semantic relationships are expressed. While Levelt and colleagues argue that associations among lexical concepts induce competition at lexical selection, interactive models offer a slightly different mechanism for lexical competition effects, namely the activation of shared conceptual features resulting in simultaneous activation of a cohort of lemmas. Both models may need to be revised in order to accommodate two seemingly counterintuitive findings in the semantic priming literature: both associative and purely semantic primes facilitate word naming but conversely produce opposing influences on picture naming. Speech production research may benefit from more communication with the semantic memory literature, which has been more focused on detailing the nature of semantic relationships and the organization of conceptual semantics. Taken together, semantic priming research suggests that the semantic representations of words exist in a highly dynamic and flexible system, allowing different types of relations to affect production depending on the demands of the task.

Lexical Selection

The process of selecting a word for expression is obviously quite complex at the semantic level. A variety of semantic influences impact the time and accuracy of lexical selection, suggesting that there may be other linguistic factors that help decide which lemma gets selected at the expense of others. Of particular influence in the current section is the importance of syntactic features in lexical selection. As stated in the introduction, whether syntactic information influences the production of individual words has been debated, largely due to the inconsistency with which syntactic variables have demonstrated an effect during single-word production tasks. Evidence in favor of a role for syntax in the representation of individual words comes from the neuropsychological literature, where patients with localized neurological insult show patterns of selective sparing or impairment as a function of grammatical class (e.g., Caramazza, 1997; Rapp & Goldrick, 2006). Most notable are the distinctions between function/content words and nouns/verbs, where individuals may be completely proficient in producing words of one class but show considerable difficulty in tasks involving the production of other word types.

Such dissociations in performance indicate that syntactic information is one dimension used to organize the lexicon, such that there may be partially distinct neural representations for nouns, verbs, and other classes of words. However, what it is less clear is whether syntactic features such as part of speech or grammatical gender are directly accessible during lexical selection, and as such, whether they help determine which word is selected in the absence of a larger syntactic backdrop, such as during sentence or discourse production. Both discrete and interactive models argue that syntactic processes are naturally part of lexical selection in that the lemma is by definition the syntactic version of a semantic concept. Intuitive evidence in favor of the syntactic lemma comes from naturally-occurring and experimentally-induced TOT states (e.g., Bock & Griffin, 2000; Caramazza, 1997), which are thought to represent a unique situation where a speaker is unable to retrieve a word's phonology despite successful lemma activation (e.g., Burke, MacKay, Worthley, & Wade, 1991; Levelt, 1989). The frustration that accompanies TOT states is thought to reflect successful selection of a specific word, i.e., lemma, giving the speaker the strong sense of being on the verge of producing the word. Critically, the type of information a speaker has access to during TOT states is taken as evidence in favor of a lemma level. For example, Italian speakers can typically identify the grammatical gender of a TOT word but have incomplete or no information about the phonological features of the word (e.g., Caramazza & Miozzo, 1997; Miozzo & Caramazza, 1997). Further evidence in favor of a role of syntax during lexical selection also comes from electrophysiological indicators of the time course of word production (see Bock & Griffin, 2000; Levelt et al., 1999, for reviews of methods). The lateralized readiness potential (LRP) is an increase in electrical brain activity that occurs prior to an overt motor response (Bock & Griffin, 2000), and studies using the LRP have suggested that speakers access syntactic information about a word prior to phonological information. Overall, research examining the properties of TOT states and the time course of naming responses during word production suggests the successful phonological retrieval does not typically occur without previously retrieving semantic and syntactic information about a word, which supports the notion that syntactic features are indeed engaged during single-word production and likely during lexical selection.

Despite these findings, research on syntactic priming has yielded highly inconsistent results, therefore challenging the degree to which syntax is automatically accessible during production. We will try to address these inconsistencies, paying particular notice to findings from syntactic priming studies and their interpretation regarding the role of syntax during lexical selection.

Are syntactic features accessed during lexical selection?

Ample research suggests that syntax is important for producing phrases (e.g., Bock, 1986) such that syntax helps determines the global structures of a speaker's utterance, the individual words selected for each position, and the order in which words are spoken. Syntactic (or structural) priming is shown when people repeat recently-produced phrases with specific syntactic structures (for a review, see Pickering & Ferreira, 2008). As described by Bock and Loebell (1990), syntactic priming occurs when production of a specific syntactic structure (e.g., noun phrase followed by a prepositional phrase) primes use of that structure in a subsequent utterance. Unlike repeated observations of syntactic priming of phrases, evidence of syntactic priming of isolated words is mixed.

The majority of research investigating syntactic influences on word production has used the picture naming task, where the grammatical class or gender of the distractor is manipulated. In the first study to investigate syntax's effect on picture naming, Schriefers (1993) had Dutch-speaking participants produce noun phrases for a target picture while ignoring distractor words that shared or did not share the target's grammatical gender. Results showed a *gender congruency effect* where utterance onset latencies were faster when the target and distractor shared grammatical gender compared to when they differed in gender. La Heij, Mak, Sander, and Willeboordse (1998) replicated Schriefers' gender congruency effect with noun phrases but failed to find any effect of gender when participants produced bare nouns (i.e., without preceding phrases; see also Schriefers & Teruel, 2000, for similar results with German). A lack of syntactic priming in picture naming has also been shown when the *grammatical class* of distractors is manipulated. For example, Pechmann and Zerbst (2002) accompanied noun pictures (e.g., trumpet) with distractors that were also nouns (e.g., balloon) or were closed-class words (i.e., words that are not nouns, verbs, adjectives, or adverbs and serve a grammatical function, such as conjunctions and articles, e.g., although). Results indicated no facilitation or inhibition in picture naming when pictures were accompanied by noun distractors compared to closed-class distractors. In order to contrast retrieval of a bare noun with retrieval of a noun in the context of a sentence, Pechmann and Zerbst conducted an additional experiment where participants read sentence fragments (e.g., Peter describes) that were immediately followed by a to-be-named picture and a noun or closed-class distractor. Participants were asked to name the picture with its accompanying definite article (e.g., the apple). In contrast to bare noun naming, syntactic interference was found in this sentence condition. Taken together, these results suggest that syntax (defined by grammatical gender or grammatical class) influences production of phrases but not production of bare nouns.

Although subsequent research investigating the role of syntax in single word production has shown some evidence of a grammatical class effect (e.g., Melinger & Koenig, 2007), researchers caution that syntax is often confounded with semantic variables such as a word's imageability (for instance, nouns are higher in imageability than verbs). This confound suggests that semantic variables could be responsible when grammatical class effects are found in picture naming. Using the same materials and procedure as Pechmann and Zerbst (2002), Janssen, Melinger, Mahon, Finkbeiner, and Caramazza (2010) demonstrated a grammatical class effect on bare noun naming, suggesting that Pechmann and Zerbst's null effect of grammatical class on bare noun naming was unreliable. However, Janssen et al. claimed that the grammatical class effect is actually an imageability effect: their results showed more interference when naming nouns that were accompanied by high-imageable compared to low-imageable distractors. Thus, although there is some evidence to support grammatical class effects in bare noun naming, these effects could be due to semantic variables such as imageability of distractors. It is therefore critical for researchers to control for semantic relationships between targets and distractors in order to isolate syntactic effects in single word production (see also Vigliocco, Vinson, Indefrey, Levelt, & Hellwig, 2004, for evidence that grammatical gender does not predict naming errors when the semantic relationship between a picture and the error is controlled).

The evidence described thus far is consistent with a large body of research showing that syntax influences speech production at the phrasal level, but syntax does not influence lexical selection in the absence of sentence context. The lack of a syntactic effect in single word production suggests that syntax does not influence competition during lexical selection (although see Caramazza & Miozzo, 1997), so distractors that share gender and/or grammatical class with targets do not influence target lemma retrieval. However, studies finding a lack of gender congruency in bare noun naming have mostly been conducted in Dutch where grammatical gender is not a property of the noun itself but is often marked on the determiner (e.g., *de kat*; translation *the cat*). In contrast, Italian marks gender by the noun's ending vowel (e.g., -*a*, or -*o*), and is thus a morphological property of the noun itself. Predicting that grammatical gender should be available during lexical selection of Italian nouns, Cubelli, Lotto, Paolieri, Girelli, and Job (2005) had participants name pictures of nouns that were of masculine or feminine gender. Distractor words were semantically related (or unrelated) and either matched (i.e., were congruent with) or did not match the picture in grammatical gender. Picture naming was slower when pictures and distractors were congruent in grammatical gender compared to when they were incongruent (for similar findings using picture-picture interference, see Cubelli, Lotto, Girelli, & Job, 2001). Cubelli et al. (2005) concluded that competition for selection occurs when the distractor shares grammatical gender with the target.

Additional evidence that syntax is activated during single word production was uncovered by Melinger and Koenig (2007), who used a homograph naming task. Participants produced stress-shifting homograph targets (e.g., *record*) whose pronunciation depended on their part of speech (the noun places stress on the first syllable, and the verb stresses the second syllable). Targets were preceded by a syntactically unambiguous prime word with one strong part of speech (e.g., noun prime such as *thorn* or verb prime such as *send*). They found that people's pronunciation of the target words depended on the prime's part of speech, with more noun pronunciations following noun primes and more verb pronunciations following verb primes (compared to single-letter controls). These results can be explained by residual activation from the prime word increasing the probability of selecting a pronunciation that corresponded to the prime's part of speech, and demonstrate that lexical selection of single words can be influenced by activation of syntax. Thus, syntax may be important for lexical selection of single words if the phonology of the to-be-produced word is dependent upon syntax to be spoken.

What we know about syntactic activation during lexical selection

Taken together, research suggests that syntax is not *automatically* activated during single word production. However, several findings indicate that syntactic features are accessible during lexical selection. Speakers in a TOT state are often able to supply the gender of the word despite an inability to retrieve phonology, and electrophysiological indicators suggest that syntactic features are activated prior to phonology during the course of picture naming (Bock & Griffin, 2000 for review). Syntactic word features might be more readily engaged when they are relevant for the production of the word, such as when syntax discriminates a word's pronunciation (Melinger & Koenig, 2007) or grammatical gender is marked on a noun (Cubelli et al., 2005).

Thus far the evidence suggests that semantic factors exert the strongest influence on lexical selection, although syntax might also play a role under certain circumstances. Given that lexical selection is the most complex stage of speech production because it requires the selection of a single item among a variety of alternates, it is perhaps unsurprising that a combination of factors is involved when a lemma is selected for production. In the next section, we will turn to the final stage of speech production, phonological encoding, where the phonological form of the word is retrieved. We will address several aspects of this process, including the possibility that phonological factors might also exert a bottom-up influence on lexical selection.

Phonological Encoding

Unlike the flexibility of lexical selection, where a number of word options may fulfill the speaker's intention, there is typically only one way to pronounce a word. As such, phonological encoding may seem like a relatively straightforward process. However, the act of retrieving and assembling the sound components of a word is actually quite complex, and a large body of research has been dedicated to unraveling the structures, processes, and temporal dynamics associated with phonological encoding. As with the other domains of speech production, priming research has made considerable contributions to our understanding of phonological-level processes. In phonological priming studies, the prime word contains some of the target's phonology, and the degree of phonological overlap is variable, sometimes consisting of a single phoneme, several phonemes, a syllable, or even an entire word. (However, when the prime and target are identical, this method is considered to be repetition priming rather than phonological priming, as they overlap at multiple levels, including phonological, lexical, and semantic representations). Unlike semantic and syntactic primes whose influence on production is variable and highly dependent on the experimental conditions assigned to the task, phonological priming almost always demonstrates facilitation (e.g., Abrams et al., 2003; Bowles & Poon, 1985; Burke, Locantore, Austin, & Chae, 2004; Costa & Caramazza, 2002; Damian & Martin, 1999; James & Burke, 2000; Jescheniak & Schriefers, 1998; Jescheniak, Schriefers, & Hantsch, 2001, 2003, 2005; Meyer & Damian, 2007; Meyer & Schriefers, 1991; Morsella & Miozzo, 2002; Navarrete & Costa, 2005; Roelofs, 2008; Schriefers et al., 1990; Starreveld & La Heij, 1995; White & Abrams, 2002; but see Jescheniak et al., 2009; Mädebach, Jescheniak, Oppermann, & Schriefers; 2011), such that target words are produced faster and/or more accurately when they are accompanied by a phonologically-related word relative to an unrelated word. Phonological facilitation is presumed to reflect the prime's activation of the phonological units it shares with the target (e.g., Cutting & Ferreira, 1999; Damian & Martin, 1999; Meyer & Schriefers, 1991; Schriefers et al., 1990), therefore speeding the time needed to prepare the target for production and articulation.

The bulk of empirical support for a phonological encoding explanation for the phonological priming effect comes from the picture-word interference paradigm and its various adaptations. When a phonologically-related distractor is presented during picture naming, latencies are facilitated relative to an unrelated distractor, an effect replicated in multiple studies (e.g., Costa & Caramazza, 2002; Damian & Martin, 1999; Jescheniak & Schriefers, 1998; Jescheniak et al., 2001, 2003, 2005; Kuipers & La Heij, 2008; Meyer & Schriefers, 1991; Schriefers et al., 1990; Starreveld & La Heij, 1995). Phonological facilitation effects are generally observed at positive SOAs (0 ms or greater; e.g., Jescheniak & Schriefers, 1998; Schriefers et al., 1990), which suggests that phonological priming effects occur during later stages of lexical processing, namely phonological encoding. Recall that semantic priming effects generally emerge at negative SOAs, indicating semantic influences at early stages, such as lexical selection.

Similar effects are reported in picture-picture interference tasks, where the distractor in this task is also a picture whose name is either phonologically related or unrelated to the target's name. Two pictures are superimposed on each other and are in different colors to distinguish the picture to be named (the target) from the one to be ignored (the distractor). For example, participants are told to name the pictures in green while ignoring the pictures in red. In studies where the distractor picture's name was either phonologically related or unrelated to the target's name, phonological priming emerges, where target naming latencies (e.g., for *bed*) are faster when the distractor is phonologically related (e.g., *bell*) than unrelated (e.g., *hat*) (e.g., Meyer &

Damian, 2007; Morsella & Miozzo; 2002; Navarrete & Costa, 2005; Roelofs, 2008, Experiment 1; but see Jescheniak et al., 2009). Meyer and Damian (2007) generalized these findings to multiple phonological relationships between targets and distractors, including shared word-initial segments (e.g., *dog-doll*), shared word-final segments (e.g., *ball-wall*), and homophones (e.g., *tank*) where the target picture represented one meaning and the distractor picture was an alternate meaning.

Phonological facilitation is also observed when speakers are asked to engage in cognitive processes beyond simple picture naming, even during tasks where the phonological form of the target is not actually produced. For example, when participants were asked to name in Spanish the color in which a picture was presented rather than producing its name, Navarrete and Costa (2005, Experiment 2; see also Kuipers & La Heij, 2008) demonstrated phonological priming in picture-picture interference. Pictures were presented in one of four colors (e.g., *verde* [green]), and the distractor name shared or did not share phonology with the color name (e.g., *vela* [candle]). Naming latencies were faster when the colors and distractor names were phonologically related than when unrelated, suggesting that phonological activation of distractors occurs even when the target's lexical representation does not need to be retrieved.

Although both discrete and interactive theories agree upon this global interpretation of phonological priming effects, a few points of contention remain as to when this process is "allowed" to begin and whether effects of the phonological prime are restricted to the phonological encoding stage. First, we will address the universally interesting question of why speakers sometimes "forget" the word they were about to produce and how priming research has helped to shed light on the specific mechanisms at fault during word retrieval failures.

What causes word retrieval failures?

Unlike other types of speech errors where the wrong word or sound is produced in place of an intended target, word retrieval failures or TOTs represent a unique situation where an anticipated target word is just beyond the speaker's current awareness. These infrequent though frustrating experiences have served as useful tools in the modeling of language and memory systems, as they represent a real world example of the rift between semantic/lexical and phonological structures. Despite their theoretical utility, there are considerably fewer studies of TOTs relative to other single-word production tasks. The methodological challenges of studying TOTs could be to blame, as TOTs occur infrequently both during daily life and in the laboratory, resulting in relatively few cases available for analysis. Notwithstanding, TOTs provide an excellent canvas for understanding phonological priming effects. Because TOTs occur when the links between the lexical and phonological representations of a word are temporarily inaccessible (e.g., Burke et al., 1991; Dell, 1986; Levelt, 1989), these weakened lemma-to-phonological connections should therefore be able to be strengthened via priming.

The idea that word retrieval failures occur at the level of phonological encoding has been supported by a number of studies demonstrating unique effects of phonological priming relative to other types of relationships. If prior production of a phonologically-related word (which should strengthen lexical-to-phonological connections) reduces the likelihood of a word retrieval failure, but a semantic prime (which should strengthen semantic-to-lexical connections) does not, then we can assume that impaired phonological connections are the source of the breakdown. Bowles and Poon (1985) were among the first researchers to examine the influence of different types of primes on single-word retrieval. In their experiments, participants read aloud a prime that contained one of four possible relationships with the target: (1) repetition, where the prime and target were identical (e.g., cat); (2) semantic relatedness, where the prime (e.g., dog) and target belonged to the same semantic category; (3) phonological relatedness, where the prime shared the target's initial phoneme, first two letters, same number of syllables, and usually stress pattern (e.g., can); (4) partial phonological overlap, where the prime contained only the target's first two letters (e.g., ca). Primes were contrasted against baseline conditions, where the prime was either an unrelated word (e.g., desk) or a string of letters (XXXXX). Target responses were elicited by a definition displayed below the prime, and participants were asked to produce the word that was being defined. Although the largest priming effects were found for repetition primes, both types of phonologically-related primes facilitated name retrieval in that responses were both faster and more accurate than the baseline conditions. In contrast, semantically-related primes did not facilitate, and in fact interfered with, target production relative to the letter string condition. These findings demonstrate a distinct advantage of phonologically-related primes in increasing successful word retrieval, which indirectly suggests that they might also reduce the likelihood of failed retrieval.

James and Burke (2000, Experiment 1) directly tested this hypothesis by applying the phonological priming procedure to the TOT elicitation paradigm. Participants read aloud a list of ten words, which sometimes was unrelated to the target and on other occasions contained five phonological primes that cumulatively contained the target's entire phonology. For example, the target *chameleon* was primed via *cacophony*, *canonical*, *ameliorate*, *battalion*, and *medallion* (target syllables are underlined here for emphasis). A general knowledge question whose answer was the target was then presented, and participants reported knowing, not knowing, or having a TOT for the target. Consistent with studies of successful word production, previously producing the target's phonology via multiple primes increased correct target retrievals and decreased TOTs relative to producing an unrelated list of words. The lack of overlap between the primes and targets at the lexical or semantic level suggests that the basis of the effect is entirely phonological in nature.

Burke et al. (2004) alternatively assessed phonological priming on TOT incidence using homophone primes, in this case referring to words that can be either an object or a proper name despite a single pronunciation. Participants first saw a definition corresponding to a homophone (prime; e.g., *pit*) or an unrelated word (e.g., *cane*) and produced the answer aloud. Following a filler picture and a filler definition, the target picture (a famous person whose last name was a homophone; e.g., *Brad Pitt*) was presented, and participants attempted to produce the name. They found a significant homophone priming effect on target naming latencies, where retrieval of the target's name was faster after producing a homophone prime relative to an unrelated word. They also demonstrated a priming effect in terms of accuracy such that more targets were produced correctly and fewer TOTs occurred following primes, although this effect disappeared when including only participants who were not aware of the phonological relationship between the prime and target. In contrast to phonologically-related primes, Cross and Burke (2004) investigated the influence of semantically-related primes on TOT incidence using primes that were famous characters and target pictures who were the actors that portrayed them. In their experiment, participants first read a question whose answer was a character name (prime), and they subsequently produced it. After a filler picture and filler question, the target picture (e.g., *Audrey Hepburn*) was presented, and participants were asked to produce the real name of the corresponding actor (target). The prime was either unrelated to the target (e.g., *Sundance Kid*) or semantically-related to the target (e.g., *Eliza Doolittle*, the main female character in the movie *My Fair Lady*). Their results showed that prior production of a semantically-related prime had no effect on either TOTs or correct retrievals of the corresponding target name relative to an unrelated prime, nor did it influence the latencies of producing the target.

Similar to TOT incidence, phonological primes have facilitatory influences on TOT resolution, the process of retrieving the target during a TOT. James and Burke (2000, Experiment 2) conducted an experiment parallel to the one on TOT incidence (see earlier description) by presenting general knowledge questions to induce TOTs. Once participants were having a TOT, they pronounced aloud a list of ten words that were all unrelated to the target or included five phonological primes that each individually contained one of the target's syllables and cumulatively contained the target's phonology. After reading the list, the original question was presented again, and TOT resolution was successful when the target could now be produced. Significant priming of TOT resolution occurred such that more TOTs were resolved after pronouncing the primed list than the unrelated list. White and Abrams (2002; see also Abrams et al., 2003) extended these findings by priming TOT resolution via three primes that contained only a single syllable within the target (the first, middle, or last), and they showed that relative to unrelated words, increased TOT resolution occurred only when the first syllable of the target was primed. Phonological priming did not occur when only the middle or last syllable of the target was provided. Abrams et al. (2003) clarified the importance of the syllable unit, as they did not find significant priming of TOT resolution when primes contained the target's first letter or first phoneme, suggesting that the initial syllable is a critical component for eliciting phonological access necessary to resolve TOTs. They also demonstrated the universality of these phonological priming effects across different manipulations, showing that (1) two first-syllable primes increased TOT resolution as effectively as three primes, and (2) producing primes aloud was not necessary, as reading primes silently also increased TOT resolution.

Together, these findings demonstrate a consistently facilitatory effect of phonological priming on TOT incidence and resolution. These influences are unique to phonological primes and do not occur for semantically-related primes, suggesting that access to phonology is the key to a word's retrieval and that an inability to do so is the cause of TOTs. Activating the first syllable of the TOT word seems to be the most critical component of successful TOT resolution, suggesting that impaired access to syllabic level units may be at fault during word retrieval failures.

Is there bidirectional interaction between lexical selection and phonological encoding?

Serial-discrete and interactive activation theories differ in when phonological forms are activated during word production. In short, serial-discrete models posit a strict order of activation where a lemma’s phonological form is activated only after lexical selection, whereas interactive activation models maintain that multiple lemmas (that are compatible with the to-be-expressed concept) begin to activate their phonological forms before lexical selection is completed. This former notion has been called cascading activation, with an ongoing continuous flow of activation between multiple partially-activated lemmas and their phonological forms. An issue highly linked to the previous question is whether the spread of activation that accompanies word production is concluded at the phonological level (e.g., Levelt et al., 1999) or in fact continues to cycle back into the system, allowing phonological processes to influence lexical selection (e.g., Dell, 1986; MacKay, 1987). The idea that phonological activation can feed back to the lexical level and impact lemma selection is contingent on the assumption of cascaded activation of phonology. In order for a phonologically-related prime to influence lexical selection of a target, it assumes that multiple lemmas can simultaneously send activation to their phonological forms prior to a single lemma being selected for production. We will first review research specific to the question of cascaded activation before addressing potential phonological influences on lexical selection.

The existence of cascaded activation has been tested through phonologically mediated priming, which occurs when a word (e.g., *goal*) that is phonologically related to a semantic associate (e.g., *goat*) of the target (e.g., *sheep*) facilitates or inhibits production of the target. Mediated priming is important to language production theories because it provides a critical test of the interactivity of semantic and phonological representations. In short, evidence of mediated priming would suggest that multiple candidates for production send activation to their phonological forms, a prediction consistent with interactive activation but not discrete models. Although there is ample evidence supporting phonologically mediated priming in word recognition (e.g., Lesch & Pollatsek, 1993; Lukatela & Turvey, 1994), congruent findings in production have been difficult to demonstrate. When found, the effects are small compared to solely phonological or semantic priming effects on production (e.g., O'Seaghdha & Marin, 1997).

In the first attempt to find mediated priming effects in picture naming, Levelt and colleagues (1991) asked participants to make a lexical decision response to an auditorily presented test probe (i.e., distractor) word or nonword. The probe followed the onset of the picture (e.g., *sheep*) but was responded to before naming the picture. In addition to responding to semantic (e.g., *goat*), phonological (e.g., *sheet*), and unrelated (e.g., *house*) test probes, participants responded to probes that were phonologically related to the semantic associate of the target (e.g., *goal*). They found no priming for these mediated probes, i.e., lexical decisions for the probe *goal* were no different from those for unrelated probes. Levelt et al. argued that if phonological associates (*goal*) of partially activated lemmas (*goat*) were activated, then priming should have been detected in the mediated condition. Thus, they concluded that even though lemmas that are semantically related to the picture are partially activated, these lemmas do not send activation to their phonological word forms. Consistent with discrete models, these data suggest that phonology is not activated until after a single lemma is selected for production.

Dell and O'Seaghdha (1991) responded to Levelt et al.'s (1991) findings by arguing that the effect of mediated words would be very difficult to detect and that the methodology used by Levelt et al. was not sufficiently sensitive to detect mediated priming. Interactive activation models posit that activation diminishes multiplicatively as it moves from one level to the next level in a system. Consequently, only a small magnitude of priming is expected for semantic associates of the picture (e.g., *goat*) because they only partially match the concept; priming will be even smaller for phonological associates (e.g., *goal*) of these semantic associates because the phonological associates receive only some proportion of the activation sent to the semantic associate's phonological form (*goat*). If the amount of activation to semantic associates (e.g., *goat*) is rather small, an even smaller proportion of this weak activation is then sent to corresponding phonological forms (e.g., /goʊt/). Further, even less activation is sent to phonologically similar forms (e.g., /goʊl/), and this amount of activation may be too small to detect in a lexical decision task.

In order to examine Dell and O'Seaghdha's (1991) claims, Peterson and Savoy (1998) tested for mediated priming by using synonyms (e.g., *couch-sofa*) instead of semantic associates (see also Jescheniak & Schriefers, 1998). Synonyms were chosen to have the greatest opportunity for equivalent activation of both alternatives. Additional changes to methodology included use of a naming task instead of lexical decision and visual instead of auditory presentation of test probes. Peterson and Savoy included phonological primes (*count*) that corresponded to the dominant picture name (*couch*) and phonologically mediated primes (*soda*) that corresponded to secondary picture name (*sofa*) names. At early and intermediate (range = 150-400) SOAs, the magnitude and time course of priming for both dominant (*count*) and subordinate (*soda*) probes was the same, suggesting that lemmas for both dominant and secondary names were equally activated and both activated their phonology. Further, these patterns of activation diverged later in processing (at 600 ms) for dominant and secondary names such that only the dominant meaning was available later in processing. This divergence at late SOAs suggests that once the dominant name is selected for production, the secondary candidate is no longer activated. In summary, Peterson and Savoy used synonyms in mediated priming paradigm to demonstrate that multiple lexical candidates initiate phonological processing.

Using a different type of target (i.e., homonyms), Cutting and Ferreira (1999) found evidence for mediated priming using a picture-naming paradigm. They chose to present auditory distractors at early SOAs (150 ms prior to picture onset), allowing the distractor to appear immediately before picture naming began. Target pictures were homonyms (e.g., *ball*), and distractors were semantically related to the meaning of the homonym not presented in the picture (e.g., if the picture was a toy *ball*, the distractor was *dance*). They found that picture naming was faster when the distractor was related to a homophone of the target, suggesting that the distractor (*dance*) activated its lemma (the social event meaning of *ball*), which in turn activated the shared word form (bɔl) and facilitated naming of the picture “ball”. Cutting and Ferreira concluded that mediated primes can influence speech production, but the effect “is small but detectable under special circumstances: when semantic alternatives are particularly interchangeable [e.g., Peterson & Savoy, 1998], or when a shared phonological representation [i.e., homophones] can receive…activation." (p. 334).

Consistent with Cutting and Ferreira's conclusion, Abdel Rahman and Melinger (2008) found evidence of mediated priming in picture naming by simultaneously presenting *two* distractors that were phonologically related to a semantic competitor. Participants took longer to name targets that were accompanied by primes phonologically related to a semantic competitor, suggesting the primes activated the semantic competitor, which inhibited naming of the target. Furthermore, Jescheniak, Hahne, Hoffmann, and Wagner (2006) found evidence of mediated priming in children but not young adults. They used a picture naming task to see if children (second and fourth graders) would demonstrate mediated priming. They reasoned that children's lexical retrieval takes longer and thus would present a situation where a mediated priming effect might be detected. Participants named pictures (e.g., *bett* [bed]) while ignoring an auditorily-presented phonological distractor or mediated distractor (e.g., *sosse* [sauce], which is phonologically related to *sofa* [sofa]). They found facilitation from phonological distractors in all age groups but interference from mediated distracters only in children. They concluded that mediated priming occurs but is difficult to detect (consistent with Dell & O'Seaghdha's (1991) argument).

In summary, although mediated priming is difficult to demonstrate experimentally, several studies have now found evidence for it under the following conditions: (1) when lexical retrieval is slowed down (as in children; Jescheniak et al., 2006), (2) when lexical competition is quite strong because of a strong semantic relationship (e.g., synonyms) between targets and distractors (Jescheniak & Schriefers, 1998; Peterson & Savoy, 1998), and (3) when the phonological overlap between mediated distractors and targets is maximized (i.e., the distractor is related to a homophone of the target (Cutting & Ferreira, 1999) or two phonologically mediated distractors are presented (Abdel Rahman & Melinger, 2008)).

Going outside the traditional mediated priming paradigms, White and Abrams (2004) presented a homophone prime paired with a single-letter word stem (e.g., *beech*-*s*_____), and participants completed the word stem with the first word that came to mind. Word stems were more likely to be completed with a semantic associate (e.g., *sand*) of the prime's homophone (*beach*), compared to word stems that were paired with unrelated, nonhomophonic words. White and Abrams concluded that phonologically mediated priming occurred because the prime *beech* sent activation to its homophone *beach*, which then activated semantically-related words such as *sand*. In another kind of priming task, Humphreys, Boyd, and Watter (2010) found mediated phonological priming using a word-based free associate generation task. Participants saw a probe word and a distractor picture presented simultaneously, and they were asked to free associate by producing the first word that came to mind when reading the probe (and ignoring the picture). Probe words (e.g., cobweb) were selected to have a highly predictable associate, which was designated as the target (e.g., spider), and distractor picture names were either phonologically related (e.g., spoon) or unrelated to the desired target response. Phonological priming occurred such that production of the target was faster when showing a phonologically-related picture relative to an unrelated picture.

Overall, there are various sources of evidence in support of the idea that multiple lexical candidates are activated for retrieval and that these candidates send activation to their phonological forms before lexical selection is completed. However, there is evidence to suggest that cascaded activation of phonology may be constrained by cognitive resource limitations, which may be why mediated priming is often difficult to detect (e.g., Mädebach et al., 2011; Oppermann, Jescheniak, Schriefers, and Görges, 2010). For example, Mädebach et al. (2011) focused exclusively on high-frequency pictures that were either visually intact or degraded in the presence of an auditorily-presented, phonological distractor. They observed phonological interference in naming the target picture when the auditory distractor was phonologically related to the distractor picture, but only in the situation where both pictures were intact. When either or both pictures were degraded, no phonological effect occurred. They interpreted these results as demonstrating constraints on the forward cascading of activation during speech production such that the phonological activation of distractor pictures is dependent on the ease with which the target and distractor pictures are processed. Distractor pictures only become phonologically activated if they are easily retrieved (when their names are high frequency and the picture is not degraded) and if processing the target picture is also easy so that sufficient resources are available for automatic activation of the distractor picture's phonology.

As indicated above, mediated priming provides a critical test of cascaded activation. At this point, considerable evidence suggests that multiple lemmas can spread activation to the phonological level before lexical selection is complete, but cascaded processing is not automatic in every context. Mediated priming effects are only detected when the strength of the prime-mediator-target relationship is maximized and cognitive resources are sufficient to enable simultaneous spreading activation among multiples lemmas. Because discrete models postulate that phonological encoding occurs only after a word is selected for production (i.e., for the selected lemma), they are unable to explain the phonological mediation effects found in these conditions. In contrast, interactive activation theories posit that selection of a target word involves automatic and continuous activation of semantically and phonologically related words. This activation spreads forward, from lemmas to phonological nodes, and feeds back from phonological nodes to lemmas. Thus, they predict phonological mediation because all phonological nodes of activated lexical candidates are at least partially activated. In any case, the general consensus is that language production involves cascaded activation from multiple lemmas to phonemes, but the strength of this activation remains contested (e.g., Roelofs, 2008).

Assuming continuous interactivity between the lexical and phonological levels would also enable bottom-up phonological influences on lexical selection. While facilitation from a phonological-related word is well established at the phonological encoding level, less is known about how the presentation of a phonological prime might affect lexical selection of a target. Indeed, potential influences of a phonologically-related word will be more difficult to detect at the level of lexical selection relative to phonological encoding because of the sequence of events involved in word retrieval. In order for a phonological prime to exert an influence on lexical selection of the target, activation must spread from the lexical representation of the prime to its phonological components and back up to the lexical representation of the target (and any other lemmas sharing that phonology). In contrast, facilitating phonological encoding only takes the first step. As such, by the time activation feeds back to the lexical level, it will be significantly diminished relative to the strength of activation provided at the phonological level.

Admittedly, phonological priming effects on lexical selection are somewhat elusive, although there is some evidence to suggest modest but meaningful phonological influences on lexical selection. For example, some picture-word interference studies have demonstrated phonological priming effects at early SOAs of -150 to -200 ms (e.g., Damian & Martin, 1999; Meyer & Schriefers, 1991; Starreveld & La Heij, 1996) or even as early as -300 ms (e.g., Jescheniak & Schriefers, 2001; Starreveld, 2000), suggesting an influence of the distractor on target production prior to phonological encoding. The influence of phonological feedback activation on lexical selection was also seen by Navarrete and Costa (2009), who observed a phonological priming effect when participants named a picture's color using a gender-marked pronominal utterance in Spanish, instead of its name. Naming the color requires access to a word's grammatical gender, which is specified only after lexical selection. Therefore, phonological priming indicates that the distractor's phonology must have facilitated lexical selection of the target picture to enable faster access to its grammatical properties. In other words, phonological facilitation occurred even when the name of the target was not produced, suggesting additional effects of phonologically-related words outside phonological encoding.

An alternative way to examine phonological influences on lexical processes is to evaluate the circumstances that promote weakened phonological facilitation or phonological interference. Because we know that effects at the phonological level are exclusively beneficial, reduced facilitation from a phonological prime implies competition at the lexical level. For example, in the TOT paradigm, some phonologically-related primes are more helpful at resolving TOTs than others. Abrams and Rodriguez (2005) conducted an experiment using a single first-syllable prime that was either the same as or different from the target in grammatical class, specifically part of speech. For example, a target *actuary* (a noun) was primed either with a same part-of-speech prime (*acrobat*, also a noun), a different part-of-speech prime (*accurate*, an adjective), or an unrelated word (*stimuli*). They found that a phonological prime increased TOT resolution only when its part of speech was different from the target. When the prime and target shared part of speech, the percentage of TOT resolution that occurred following the prime was equivalent to that observed after an unrelated word. Abrams, Trunk, and Merrill (2007) replicated these findings and demonstrated that the relationship between part of speech and phonological priming of TOT resolution changes in old age. Adults aged 75-89 did not show increased TOT resolution in any circumstances (their resolution following different part-of-speech primes was equivalent to resolution following unrelated words), and in fact their TOT resolution was *inhibited* by same part-of-speech primes, evidenced by less resolution after primes compared to unrelated words. These findings more precisely specify some of the constraints under which phonologically-related words are not beneficial to speech production, i.e., shared grammatical class and aging. Because grammatical class effects are certainly not occurring at the level of phonological encoding, we can infer that the interaction between phonological and syntactic factors is occurring at the level of lexical selection. Clearly, there is substantial variability in the influence of phonological and mediated primes on speech production across methodologies, time courses, and developmental age groups. Therefore, further research is needed to identify the conditions that allow for the simultaneous activation of multiple lexical candidates' phonologies and significant feedback activation to the lexical level.

Although there is a paucity of research directly examining the influence of phonological processes on lexical selection, a few studies do suggest that phonologically-related words can impact lexical selection under certain circumstances. Such a conclusion is readily adapted into interactive activation models, where activation is assumed to reverberate between the lexical and phonological levels. However, discrete models have more difficulty in explaining these data, given the one-directionality of connections between the two systems.

What we know about phonological encoding

A substantial portion of what we know about phonological encoding has been built based on findings from priming studies. Thus far, we can say with certainty that word retrieval failures are caused by a breakdown in retrieval at the phonological encoding level, a problem that can be effectively offset by strengthening lemma-to-phonology links through priming. Further, throughout the course of word production multiple lemmas sometimes spread activation to the phonological system, although the degree of cascaded activity is confined by the amount of resources currently available to the speakers. This cascading activation allows for phonological features to sometimes bounce activation back to the lexical level, thereby exerting an influence on lexical selection.

CONCLUSION

The studies described in this chapter demonstrate the extent to which priming research has served as the most influential experimental method for tapping into the organization and mechanics of the speech production system. While this review is far from exhaustive, it nonetheless addresses several of the most pertinent questions in the field of speech production research and the current status of these questions in light of recent evidence. With some conclusiveness, priming research suggests that words relate to one another at the level of both shared semantic features and lexical association, although these types of relationships appear to be encoded at different levels in the system. Both discrete and interactive models would be improved by greater specificity in characterizing the conceptual semantic system and its interaction with the lexical level, which may require improved integration of findings from the semantic memory literature. Distinguishing the factors that influence lexical selection remains a difficult challenge for language researchers. While there is some evidence to suggest that syntax is an important characteristic of lemmas and therefore an inherent part of lexical selection, research on syntactic priming has yielded inconsistent outcomes regarding the role of syntactic features on single-word production. Conservatively, the overall pattern of findings suggests that syntax is available to speakers during lexical selection, but activation of syntactic features like grammatical class or gender is not automatic. Finally, phonological priming studies have provided considerable evidence for interactive lexical-to-phonological connections, where free-form spreading activation allows for multiple lemmas and their phonological forms to be simultaneously activated. However, there are limits on the degree of cascaded activation and the extent to which phonological activation can influence lexical selection, which reflects limits in the capacity of cognitive resources and diffusion in the activation produced by the prime.

Beyond these core theoretical questions, priming research continues to be extended to gain a better understanding of how words are represented, organized, and accessed by speakers. Of particular interest is how these processes might develop throughout the lifespan or may differ as a function of the language being spoken or the number of languages at the speaker's disposal. For example, the effectiveness of priming might improve with age as individuals learn more words and form stronger semantic connections between them. Conversely, neurobiological (e.g., gray and white matter atrophy, declines in neurotransmitter function) and cognitive (e.g., reductions in global cognitive resources, slowed processing speed) changes associated with age might weaken connections between words and within a single word, resulting in less efficient spreading of activation in the system (e.g., Burke & Shafto, 2008; Hedden & Gabrieli, 2004; MacKay & Burke, 1990). Overall, it is clear that the application of priming research to new and novel questions about human behavior will continue to play an important role in the development of cognition, memory, and language theories.

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Reviewed by Meredith Shafto, Ph.D., University of Cambridge, Department of Experimental Psychology, Centre for Speech Language, and the Brain.

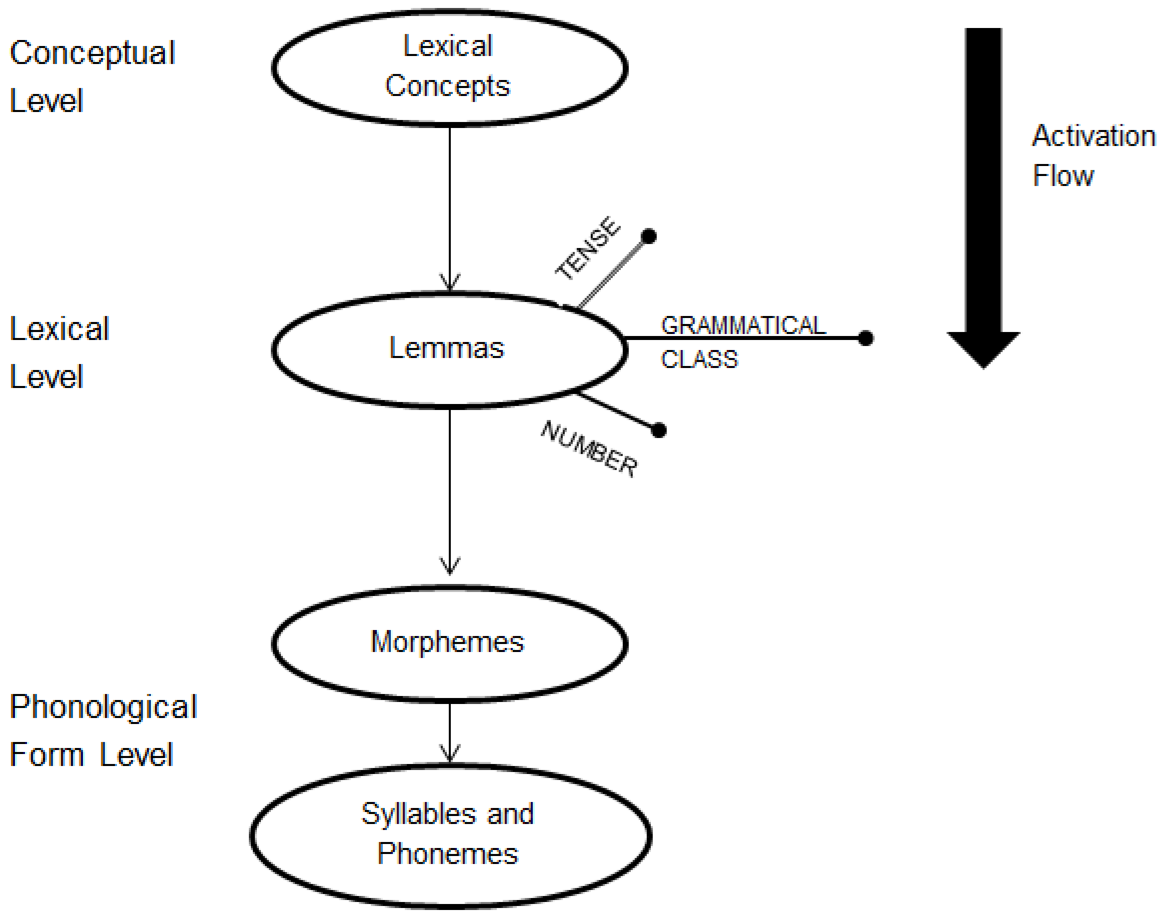

Figure 1. Schematic of discrete feed-forward model, with dual-stage lexical retrieval (lemma selection) and nondecomposed semantics (e.g., Levelt et al., 1999).

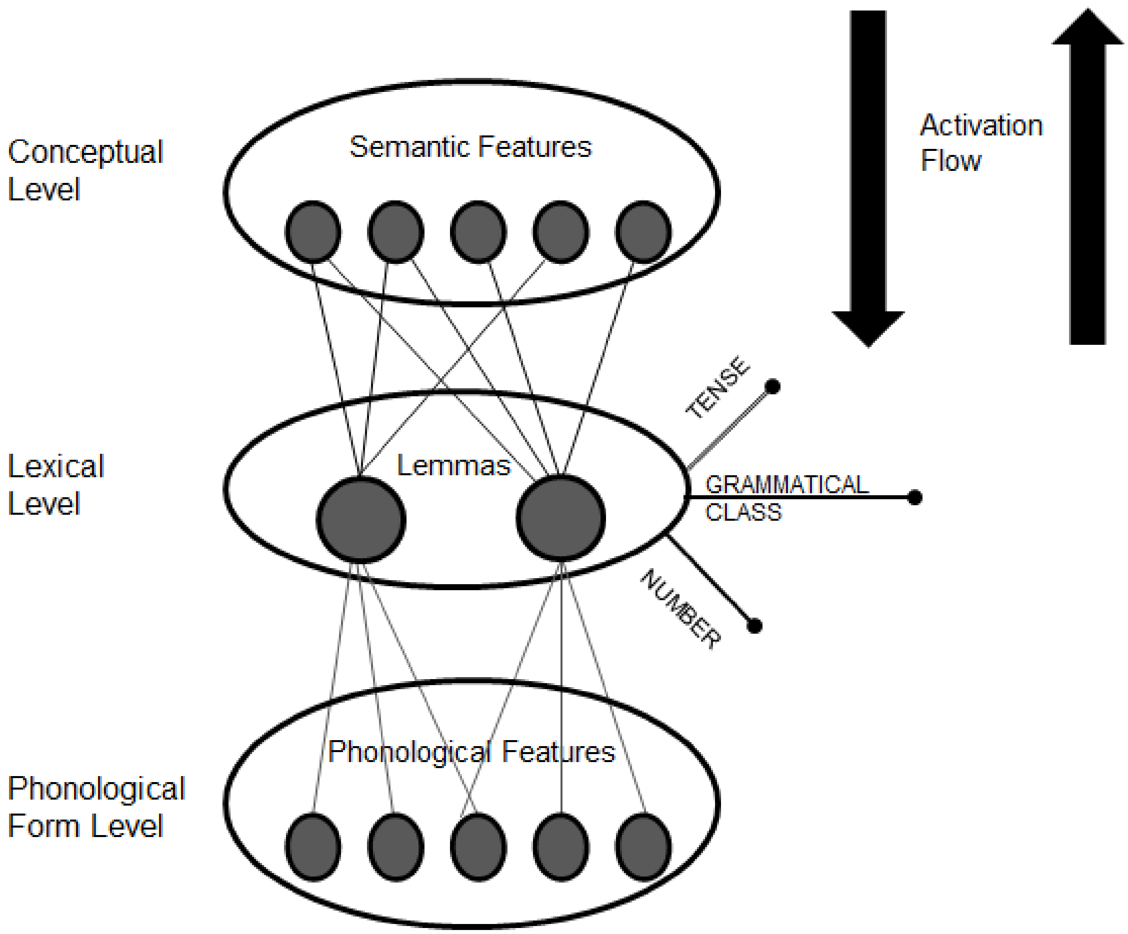

Figure 2. Schematic of interactive models with dual-stage lexical retrieval and componential semantics (e.g., Dell, 1986; MacKay, 1987).