Phonological Processing: The Retrieval and Encoding of Word Form Information in Speech Production

Matthew Goldrick

Abstract

Sound forms "give voice" to complex conceptual, syntactic, and morphological structures. This article examines the first steps in spoken production processing toward this goal. The first section argues for a stage of word form processing that is influenced by lexical factors (reflecting the input to phonological processes) but is not affected by phonetic factors (because these are represented in subsequent processes). The second section reviews behavioral and electrophysiological data suggesting that within phonological processes, multiple dimensions of phonological structure (segmental, syllabic, and metrical) are independently represented and retrieved; these are subsequently linked or coordinated with one another to provide input to phonetic processes. Finally, the influence of the input to phonological processing on the retrieval of phonological structure is examined (e.g., the influence of partially activated, semantically related words on the speed and accuracy of phonological processing).

Key Words: phonology, interaction, syllables, metrical structure

Sound forms are a linchpin of the link between speaker and hearer. They "give voice" to complex conceptual, syntactic, and morphological structures, providing the hearer with the information needed to recover the speaker's intentions. This article examines the level of processing that realizes the first steps towards the goal: phonological processes.

The first section of this article situates phonological processing within other processes in spoken production. As shown in Figure 14.1, phonological processes take as input information about the lexical representations that have been selected to express the speakers' intended message (see Word Production: Behavioral and Computational Considerations by Dell, Nozari, and Oppenheim for discussion). The word forms corresponding to these lexical representations are spelled out or specified by retrieving distinct dimensions of form information from long-term memory and linking them together, encoding a complex phonological representation (these aspects of processing are sometimes discussed in the literature as separate processes, phonological retrieval, and phonological encoding.) As depicted at the bottom of Figure 14.1, these abstract phonological structures serve as input to phonetic and motor processes that produce articulatory gestures for discussion, see “Phonetic Processing” by Buchwald; “The Temporal Organization of Speech” by Poulsen & Goldstein; and “Neural Bases of Phonological and Articulatory Processing” by Ziegler & Ackermann. The first section reviews evidence supporting this overall functional architecture. Data from a variety of methodologies and populations argue for a stage of word form processing that is influenced by lexical factors (reflecting the input to phonological processes) but is not affected by phonetic factors (as these are represented in subsequent processing stages).

The second section of the article examines the internal structure of phonological processing in greater detail. Behavioral and electrophysiologis...
The article argues for a system of phonological processes, including gestures (e.g., "speech" by Buchwald; "rhythm" by Pouplier and Ackermann). The data suggest that within phonological structure, multiple dimensions of phonological structure (segmental, syllabic, and metrical; see "Phonology and Phonological Theory" by Baković for further discussion) are independently represented and retrieved; these are subsequently linked or coordinated with one another to provide input to phonetic processes. Figure 14.1 illustrates some of these dimensions of structure for the target word “leopard” segments (e.g., /l/); syllables (e.g., the first syllable is a stressed CV, /re/); and metrical feet (e.g., “leopard” consists of a stressed CV followed by an unstressed syllable).

The following section examines in greater detail the influence of the input to phonological processing on the retrieval of phonological structure. For example, as shown in Figure 14.1, interactions with semantic and phonological processes lead to the partial activation of lexical representations that are semantically (e.g., <tiger>) or phonologically (e.g., <shepherd>) related to the target. These in turn activate their corresponding phonological representations (e.g., <tiger> activates the segment /g/), influencing the speed and accuracy of phonological processing in production.

Finally, the article concludes with an overview of the advances in the understanding of phonological processing since the seminal work of Garrett (1975). Directions for future research that can build on these insights are discussed.
Linking Lexical and Phonetic Structure

The place of phonological processing within the production system is to bridge lexical/morphological representations and the processes that construct articulatory plans. This section argues for this functional architecture through a review of data from neuropsychological and neuroimaging studies and behavioral studies of unimpaired individuals.

Evidence from Acquired Neurological Deficits

If phonological processing is distinct from more peripheral phonetic processes, and the degree of interaction between these processes is sufficiently limited in strength, one should be able to observe cases of acquired neurologic impairments affecting word form processing that selectively target phonological vs. phonetic processing. Deficits to phonological processing should be marked by sensitivity to lexical factors and insensitivity to phonetic factors; deficits to subsequent phonetic processes should exhibit the contrasting pattern of performance.

Goldrick and Rapp (2007) argue that performance on picture naming versus repetition could be used to distinguish such impairments. Because picture naming requires access to lexical (word/morphological) representations, a selective impairment to phonological processing, in particular to the retrieval of phonological information, should impair naming. However, such a deficit should leave repetition performance intact; the task can be performed without accessing lexical representations (Hanley, Dell, Kay, & Baron, 2004). In contrast, a selective deficit to processes subsequent to phonological processing should equally impair all speech production tasks.

Goldrick and Rapp (2007) document two individuals that exhibit these contrasting patterns of performance. Both individuals produce a variety of sound-related errors (mitten→muffin; trumpet→chirper) suggesting that their deficits affect processes subsequent to lexical access during the processing of word forms. Subsequent analyses reveal a nearly complementary set of factors influencing these individuals' behavior. The performance of the individual with a phonological processing deficit is affected only by word-level variables (e.g., he is less accurate on low-frequency words) but not by phonetic complexity (e.g., he shows no difference in accuracy on high- vs. low-frequency sound structures). The individual with a deficit to processes subsequent to phonological processing exhibits the complementary pattern. These contrasting patterns of performance are consistent with the view that phonological processing is sensitive to lexical properties and manipulates relatively abstract representations of sound structure.

Romani and colleagues (Romani & Galluzzi, 2005; Romani, Olson, Semenza, & Graná, 2002) also report patterns of acquired production impairments consistent with a distinction between more and less abstract word-form representations. They find that individuals with articulatory planning deficits (nonfluent speech in the absence of peripheral motor problems) are sensitive to phonetic complexity (e.g., complexity of syllable structures). In contrast, individuals with fluent speech show no such complexity effects but are sensitive to the word-level factor of lexical frequency. Note that in contrast to Goldrick and Rapp (2007), these fluent patients have deficits affecting all spoken output tasks. This may reflect disruptions to distinct aspects of phonological processing (e.g., retrieval of segmental structure vs. linking of segmental and syllabic structure).

Evidence from Functional Neuroimaging

If phonological processing serves to bridge lexical selection and phonetic processes, and the degree of interaction between phonological and phonetic processing is sufficiently limited in strength, there should be brain regions involved in word form processing that are sensitive to word-level variables but not to phonetic complexity. Imaging studies of neurologic-intact individuals report results consistent with these predictions. Form-related processes in speech production engage a network involving posterior temporal and frontoparietal brain regions (Indefrey & Levelt, 2004; Indefrey, 2011; see “Neural Bases of Phonological and Articulatory Processing” by Ziegler & Ackermann for more detailed discussion). Activity in temporoparietal regions (e.g., posterior superior temporal gyrus) is modulated by lexical frequency (Graves, Grabowska, Mehta, & Gordon, 2007; Graves, Grabowska, Mehta, & Gupta, 2008; Wilson, Isenberg, & Hickok, 2009) but not by phonetic complexity (i.e., frequency of sound structures; Graves et al., 2008; Papoutsi et al., 2009). In contrast, activity in frontoparietal regions is reported to be modulated by these measures of phonetic complexity (see Graves et al., 2008; Papoutsi et al., 2009, for discussion of specific regions). These contrasting patterns are consistent with a view that associates posterior temporoparietal regions with an abstract level of phonological processing, sensitive to word-level proper detailed review of retrieved imaging data concerning phonological processing.

Evidence from Exp Studies: Speech Errors

Evidence from behavioral studies suggests that the segmental representation factors but not sensitivity to speech sounds, specifies most basic level of sound distinction across sounds. For consonant place of articulation tongue at the tip vs. the back palate for the consonant constriction for /s/ vs. its absence due to consonant constriction for /l/. For example, featureal tense on the likelihood of a speech error. The high /l/, differing solely in its representation in terms of the presence of fricative noise, whether the vocal fold constriction for /l/ is not among the features represented in the phonological representation of /l/.

Oppenheim et al. (2008) report a number of segmental errors produced by participants monitor the contents of the sentence. When conditions mimicked the reading of written text, participants produced errors on sounds which were not overtly produced (e.g., /l/, /r/, /s/). This is consistent with an abstract level of word-form segmentation but not features at higher levels of processing at this level of information.
to word-level properties (see Indefrey, 2011, for a detailed review of related spatial and temporal neuroimaging data concerning the contrast between phonological processing and phonetic encoding).

**Evidence from Experimental Behavioral Studies: Speech Errors and Priming**

Evidence from behavioral studies suggests that production processes operating at the granularity of segmental representations are sensitive to word-level factors but not sensitive to more fine-grained aspects of speech sounds, specifically, features. These are the most basic level of sound representation, and possibly articulatory properties of sounds. Segments, these include such aspects as the place of articulation (e.g., the placement of the tongue at the front of the hard palate for /t/ vs. the soft palate for /k/); the manner of articulation (e.g., the stopping of airflow for /t/ vs. the presence of friction noise in /s/); and voicing (roughly, whether the vocal folds are vibrating during the consonant constriction—contrast vibration during /d/ vs. its absence during /s/). Features are clearly beyond the scope of speech production system. For example, featureal similarity exerts a strong influence on the likelihood that two segments interact in a speech error. The highly similar segments /b/ and /p/ differ most in voicing, and frequently interact in errors. In contrast, /b/ is much less likely to interact with segments that differ not only in voicing but also in place and manner of articulation (e.g., /b/; Wildshire, 1999). Segments are a level of representation that links groups of features together and enforces their temporal coordination. For example, this level specifies that in “bat” the labial closure and voiced features of the /b/ are coordinated in time, whereas voiceless is coordinated with the alveolar closure in /t/. In contrast, the associations between voiceless and labial/alveolar are reversed for the word “pad.”

Oppenheim and Dell (2008, 2010) examine segmental errors produced in “inner speech,” where participants monitor their silently produced speech. When conditions minimizing articulation are used (see Oppenheim & Dell, 2010, for discussion) segmental errors on tongue twisters produced during inner speech are less sensitive to featural similarity than overtly produced errors (Oppenheim & Dell, 2008, 2010). This is consistent with a relatively abstract level of word-form processing, specific for segmental but not featural content. Furthermore, processing at this level is influenced by word-level information. Oppenheim and Dell find that inner speech errors exhibit a lexical bias; segmental errors are more likely to produce word outcomes than nonword outcomes (e.g., “wreath” → “ref” is more likely than “wreath” → “leath”). This is consistent with a level of word form processing that is sensitive to word-level factors but insensitive to fine-grained aspects of form (see Olson, Romani, & Halloran, 2007, for a report that errors arising due to a phonological processing deficit are sensitive to featural structure).

Chronometric paradigms provide additional support for a level of processing specified for segmental but not featural content. Roelofs (1999) uses a form-preparation paradigm (after Meyer, 1991) in which the names of pictures in a blocked trial share the same initial segment (and only the initial segment; e.g., book, bear) or, participants named the pictures more quickly when pictures in a block had highly dissimilar initial segments (e.g., file, kite). This form-overlap advantage is not found when the pictures in a block have initial segments that are highly similar (but not identical) in their featural content. For example, no priming effect is found for sets such as “book, pear,” even though these initial segments are highly similar (sharing the same place and manner of articulation, differing only in voicing). Roelofs (2003) finds similar results when the target segments are in the same language (e.g., book, bear) or different languages (e.g., book, bloem—“flower” in Dutch; note this study uses a paired-associate version of this paradigm, where speakers memorise prompt-response pairs instead of naming pictures). These findings suggest that segmental priming can occur at a level of processing that is not sensitive to featural structure.
suggesting that repetition of identical sounds results in a higher-than-chance error rate on the second segment (e.g., the /b/ in bill will have more errors in a sequence like bag bill than tag bill). This segmental repetition effect occurs for repetitions of onset, nucleus, and coda segments. In contrast, across these positions there is no consistent, significant effect of repetition of features. The only exception to this is a weak effect of featural repetition (e.g., higher error rates on peg bill), limited to initial sounds. The overall pattern, showing highly attenuated featural similarity effects in the presence of strong segmental identity effects, supports a segmental level of processing that is relatively independent of featural structure.

**Interim Summary: From Lexical to Phonetic Representations**

In order to produce speech, it is clear that speakers must have representations of articulatory information. The data reviewed previously suggest a level of word-form processing that operates over more abstract representations (see Phonetic Processing by Buchwald for further discussion). Phonological processing is insensitive to featural complexity and does not specify featural structure. Furthermore, this level of processing is influenced by lexical properties, consistent with a cognitive process that receives input from lexical selection processes.

**Form Representations in Phonological Processes**

**Phonological Representations**

**Beyond the Segment**

In addition to segmental representations, many phonological theories assume that segment-sized units are grouped into basic prosodic constituents, syllables (Selkirk, 1982). Syllables form the most basic level of a set of representations specifying themetrical structure of an utterance—roughly, the grouping of segments into structures that convey rhythm, stress, and intonation (see Goldsmith, 1990, for a review). Many of these are critical for understanding connected speech (see “Phrase-level Phonological and Phonetic Phenomena” by Shattuck-Hufnagel). In the case of single words it suffices to focus on the level of structure immediately superior to the syllable, the foot. These organize syllables and groups and express the relative prominence of different syllables (i.e., stress). Lexical stress refers to cases where the position of prominence is idiosyncratic to particular lexical items. For example, in Italian, stress tends to fall on the second to last syllable (e.g., ancora, more still) but sometimes (unpredictably) falls in other positions (e.g., ancora, anchor).

Distinct from segmental and syllabic structure is linguistic tone (Goldsmith, 1990). Roughly speaking, tonal distinctions are conveyed by variations in pitch. In languages such as English, tone patterns are used at the level of sentences to convey information in meaning. For example, in American English, questions typically end with a rising pitch pattern, whereas statements typically end with a lower pitch (contrast “You saw Mary? with “You saw Mary.”). In other languages, tone patterns are associated with individual syllables and distinguish different lexical items. For example, in Mandarin, “ma” with a falling pitch pattern means “scold” while the same syllable with a rising pitch means “hemp.” Because this latter type of tone pattern is associated with particular words, it is referred to as lexical tone.

The data reviewed next suggest that these distinct aspects of structure are represented within phonological processing. Given this, it is important to consider how they are integrated in representation and processing. As discussed in the following sections, much of the behavioral data suggest that these dimensions of structure are indeed linked together to encode a coherent phonological representation. However, there is also considerable dependence of independence between different dimensions. This accords with autosegmental phonological theories (see Goldsmith, 1990, for a review). These abandon the traditional focus on the segment as the central organizing structure of phonological representations. Instead, distinct aspects of phonological structure (e.g., segments, features, syllables) are viewed as independent representational “items” that are coordinated with one another. This “integrated-yet-independent” conception of representational structure provides a useful conceptual framework for understanding patterns in speech production (see Badecker, 1996, for further discussion).

**SEGMENAL AND SYLLABIC STRUCTURE**

It is clear that segmental and syllabic structures are linked within phonological processes. In spontaneous speech, segmental speech errors tend to respect syllable position, suggesting an integration of syllabic and segmental structure (Voudes, Brown, & Harley, 2000). For example, for a target sequence like “bad cat,” the error “bad cat” (where the misplaced segment occurs in the same syllable position in a different syllable) is more likely to occur than “bad cab” (where a different position effects are at least at different levels). Rapp (2011) report that children with deficits in syllabic structure are particularly sensitive to segmental errors. The implicit prior of segmental, not tonal (above) are sensitive to the same number of phonological processes.

How can one represent and syllable structure serve as representations in segmental independent schemes of structure independence? Sevald, Dell, & Caramazza’s (1998) view that the retrieval of an independent segmental and syllable structure is that the latter, the former processing integrates into a single representation.

**Independent Represenations of Segment and Syllable**

Consistent with the view of languages such as Spanish and Japanese, information about phonological processes is independent. Therefore, segmental and syntactic errors tend to respect an integration of segmental structure with a significant number of constraints. In English, segmental errors (e.g., Verbiage) higher rates of extra-error-induction tasks (Meyer, 2000). Damper priming results show that independent of syllable structure latencies when syntactic and segmental errors occur in different utterances occur in different units suggest that
"bad cab" (where the misplaced segment moves to a different position in a different syllable). These effects are at least partially attributable to phonological processes. Romani, Galluzzo, Bureca, and Olson (2011) report that the segmental errors of individuals with deficits to this process tend to preserve the syllabic structure of the target. Goldrick, Folk, and Rapp (2010) report that lexical substitutions arising subsequent to a deficit to phonological processes are sensitive to segmental and syllable structure. Finally, the implicit priming effects driven by overlap at the segmental, not featural, level (Roelofs, 1999; see above) are sensitive to whether or not words share the same number of syllables (Roelofs & Meyer, 1998). All of these results suggest that both aspects of phonological structure are integrated within phonological processing.

How can one account for the linking of segmental and syllable structure? Under one view, syllables serve as representational units controlling access to segmental information; alternatively, they are independent schemas or frames that organize and structure independently represented segments (see Sevald, Dell, & Cole, 1995, for a review). Under the former view, phonological processing involves the retrieval of an integrated representation of segmental and syllable structure (Romani et al., 2011). Under the latter, these two aspects of phonological structure are retrieved independently; subsequent processing integrates these two dimensions of structure into a single representation.

**Independent Representation of Segment and Syllable**

Consistent with the latter perspective, studies of languages such as English, German, Dutch, and Spanish suggest that syllabic and segmental information are represented independently during phonological processes. Although segmental speech errors tend to respect syllable position (suggesting an integration of syllabic and segmental structure), a significant number of errors violate such constraints. In English, this exceeds 20% in spontaneous errors (e.g., Voulsen et al., 2000) with even higher rates of exceptions observed in experimental error-induction tasks (e.g., Dell, Reed, Adams, & Meyer, 2000). Damian and Dumay (2009) report priming results showing an effect of segments independent of syllable position. They find faster naming latencies when segments are repeated in English adjective-noun utterances, even when these segments occur in distinct syllable positions. These results suggest that the representation of segmental identity is sufficiently independent from its syllable position to allow a separation during processing.

With respect to syllable structure, in some priming paradigms syllable structure can be primed independent of segmental content (see Schiller & Costa, 2006, for a full review of the mixed pattern of priming results across paradigms; see Harm & Costa, 1999, for an account of related evidence from speech errors). For example, using auditory and visually presented prime words, Costa and Sebastin-Gallés (1998) show that in Spanish shared syllable structure exerts a priming effect on picture naming independent of shared segmental structure. Sevald et al. (1995) found that English speakers can more quickly repeat pairs of words with overlapping syllable structure. For example, in the word pair kil tafr-ner (where—indicates a syllable boundary), both words share an initial consonant-vowel-consonant (CVC) structure. This is repeated faster than kil af-ner where the second word has an initial CVCC syllable (n.b. this effect is independent of length effects on naming). Sevald et al. find that there is no additional benefit for sharing the same segments, suggesting this effect derives purely from shared syllable structure (e.g., kil kil-ner is no faster than kil tafr-ner). Spontaneous speech errors also provide support for the representation of the syllabic role (i.e., CV structure) independent of segmental identity. Harm & Costa (2002) finds that spontaneous speech errors in Dutch and Spanish are influenced by the CV structure of surrounding syllables (see also Stemmer, 1990). This set of findings supports a representational distinction between segments and syllable structure within the production system. However, the association of such effects with phonological processing is far from unambiguous. Because segmental and syllabic structure is also present in phonetic processes (see "Phonetic Processing" by Buchwald for discussion), the absence of independence evidence it is possible to attribute these effects to other stages of word-form processing.

Assuming that effects such as these do arise within phonological processes, many authors have proposed the independent, parallel retrieval of segmental and syllabic structure during phonological processes, followed by a process that associates segments to specific syllable positions (see Shattuck-Hufnagel, 1979, for one of the first explicit proposals of such an account). Within this broad framework, a variety of contrasting proposals have been advanced for the representation and processing of these two aspects of structure (discussed in more detail in the following sections).
Structure of Syllabic and Segmental Representations

In addition to representing the identity of segments, phonological processes must represent their serial order; otherwise, one could not distinguish words like “cat” and “tack.” Consistent with this observation, Goldrick et al. (2010) report that serial position influences the activation of form-related lexical representation during phonological processing. They examine word substitution errors (e.g., “beaver” → “weaver”) produced by an individual with a deficit to phonological processes. The rate at which these errors shared segments with the target in specific linear positions exceeded that predicted by a theory in which the position of segments is not represented. However, these are also significantly more likely to share syllabic length with their targets than expected on the basis of shared segmental structure (Goldrick et al., 2010). Additionally, cross-position segmental transposition errors and priming effects (reviewed previously) suggest that the representation of segment identity is not intrinsically bound to particular serial positions. These observations raise the possibility that some aspects of the specification of segmental serial order are related to the linking of segmental and syllabic structure.

Theories disagree on the amount of syllabic information that is specified during retrieval. Levelt, Roelofs, and Meyer (1999) adopt a minimalist approach, assuming that only the number of syllables is retrieved. Under this account, the particular structure of each syllable is computed based on the retrieved segments. Others have proposed that more structure is specified. Shattuck-Hufnagel (1992) proposed that in addition to syllabic information (and other aspects of prosodic structure), segments are linked into a representation that specifies position within lexical items. Other studies suggest that the arrangement of consonants and vowels within each syllable is also stored and retrieved. This perspective is consistent with the effects of syllable structure independent of segmental content reviewed previously (assuming such effects arise within phonological processes).

Processing of Segmental and Syllabic Structure

A range of proposals have been advanced regarding how segmental and syllabic structure are retrieved and linked. Some theories assume that the retrieval of segments and their association to syllable positions are incremental (Levelt et al., 1999). Others have assumed that segments are retrieved in parallel but associated to the frame incrementally (O’Seaghdha & Marin, 2000). Additional debates concern the nature of mechanisms accomplishing the linking or binding of segments to syllable positions (for discussion of contrasting proposals, see Dell, Burger, & Svec, 1997; Levelt et al., 1999; Shattuck-Hufnagel, 1992; Vouk et al., 2000). Some authors (e.g., Jacquet & Scott, 2006; Peattie, Scroffen, & Martin, 1987) have linked this linking/binding process to the phonological output buffer. This refers to a set of processes that maintain the activity of phonological representations while the linking processes (and perhaps subsequent phonetic and articulatory processes) are engaged (Caramazza, Mille, & Villa, 1986; see Shallice, Rumiati, & Zadini, 2000, for a review).

Chronometric and electrophysiological studies provide support for some degree of incrementality in the retrieval or linking of segmental and syllabic structure. Meyer (1991) finds that implicit priming is contingent on prime words sharing initial structure; overlap in noninitial positions fails to produce priming. As discussed in preceding sections, this priming paradigm appears to tap into abstract segmental representations (Roeleveld, 1999), suggesting this effect arises within phonological processes.

Further support for incrementality comes from studies of monitoring. Wheelton and Levelt (1995; see also Wheelton & Morgan, 2002) find that monitoring times for inner speech increase as segments appear at later positions in the word. Van Turennot, Hagoort, and Brown (1997) find a similar latency increase both behaviorally and in electrophysiological measures. Wheelton and Levelt (1995) find that monitoring latencies for inner speech are sensitive to syllable boundaries. Participants are significantly faster at monitoring for a sequence of segments that falls within a single syllable (see also Morgan & Wheelton, 2003). Furthermore, the increase in reaction times across linear positions in the word is influenced by syllable boundaries. Although reaction times increase for segments occurring at later positions in the word, there is a much greater increase in reaction times when syllables boundaries are crossed. For example, the target word “lifter,” the difference in monitoring times for /li/ and /li/ (within the same syllable) is much smaller than the difference between /li/ and /li/ (across syllables). Wheelton and Levelt (1995) argue that these effects do not arise within phonetic processes because monitoring performance is not affected by performance of a concurrent articulatory task and there is no significant correlation between the acoustic durations of speakers’ productions (indexing articulatory latencies). The experiments phonologic effects. However, they may rely on processes in speech perception; Levelt effects observed in the absence of these addition.

Segmental and Representation

Research supports retrieval of segmental information is almost exclusively for English, German, and other languages in which the degree to which segments are separated can be clearly observed.

Recent studies suggest that for speech, segmental information is retrieved more tightly together. Although English is not as well-ordered as Mandarin, syllabification occurs in Mandarin with the use of character structure. Studies in Mandarin of syllables and segmentation require only single word priming in contrast to primes in Mandarin speech of an entire syllable. O’Seaghdha, Choo, and others have also exhibited structure in this task. This has been argued to come from the onset argument (Kubozono, 1985, for Production) where effects of the first of these paradigms, effects are found in masked priming latency is low but masked phonological effects are found in masked phonological processing (Kubozono et al., 2011).

On the other end, such as English and Arabic, speech is processed in another manner.
Additional debates achieve mechanistic accomplishments to syllable and segmental structures to syllable and segmental structures. Counterproposals, as Levelt et al. (1999), Wassen et al. (2000), and Scott, 2006; Pet, have linked this linking/segmental output buffer. Processes that maintain the segmental representations while these processes share phonetic, subsequent phonetic, input/output buffer (Caramazza, Fabbri, & Rumiati, 1999). Physiological studies indicate that of incrementality between segmental and syllabic structures that implicit priming in the normal hearing initial segmentations fail to produce evidence. Brooding sections, this evidence maps onto abstract segmental structure (1999), suggesting more knowledge not processional.

Incrementality comes from Wheeldon and Levelt (1997). Morgan (2002) find that for the monitor speech increase in the word. Brown (1997) find that behaviorally and reactively. Wheeldon and Levelt (1997) report longer segmental latencies for syllable boundaries. Faster at monitoring words that falls within a single syllable (1999). Reaction times across syllable boundaries is influenced by syllable length. Reaction times increase for longer structures in the word. Meyer (1999) report in reaction times as the word length increased. For example, a difference in monitoring (for the same word before the same syllable) is much larger between /t/ and /l/ (Krems and Levelt 1995) than /s/ and /l/ (Krems and Levelt 1995). This suggests that within phonetic contexts, performance is not random. Performance may vary, but control appears to be related to the languages' productions (indexing articulation time) and their monitoring latencies. The exclusion of phonetic processing supports phonological processes as the locus of these effects. However, performance in monitoring tasks may rely on processes outside of phonological processes in speech production proper (e.g., speech perception: Levelt et al., 1999). The incrementality effects observed here may therefore reflect the influence of these additional processes.

Segmental and Syllabic Representations across Languages

Research supporting the parallel, independent retrieval of segmental and syllabic structure has been almost exclusively drawn from a set of highly similar, historically related languages (e.g., Dutch, English, German, Italian, Spanish). A smaller body of data drawn from other languages suggests that the degree to which segments and syllable structure are separated can vary as a function of linguistic experience.

Recent studies of Mandarin and Japanese suggest that for speakers of these languages, segmental structures are more tightly integrated with suprasegmental structure. Although speech errors in such languages as English frequently involve single segments (see above), Mandarin speech errors frequently involve movement of entire syllables (Chen, 2000). Priming studies in Mandarin also suggest a tighter coupling of syllables and segments. In English and Dutch, the implicit priming paradigm of Meyer (1999) requires only single segment overlap to induce priming; in contrast, implicit priming is observed in Mandarin speakers only when there is overlap of an entire syllable (Chen, Chen, & Dell, 2002, O'Seaghdha, Chen, & Chen, 2010). Japanese speakers also exhibit sensitivity to suprasegmental structure in this task. Syllables in Japanese have been argued to consist of two groupings of segments: the onset and vowel versus the coda (see Kubozono, 1985, for evidence from speech errors). Production priming in Japanese requires the overlap of the first of these units. In the implicit priming paradigm, effects are not found with onset overlap alone, but require overlap of the onset and vowel (Kureta, Fushimi, & Tatsuni, 2006). Similar results are found in masked onset priming (where word naming latency is reduced by presentation of a masked phonologically related word; Vethomchot et al., 2011).

On the other end of the scale from languages such as English and Dutch, phonological processes in Arabic speakers seem to have an even weaker coupling of segmental and syllabic representations. Berg and Abd-El-Jawad (1996) contrast spontaneous speech errors in English, German, and Arabic. Whereas in English and German most segmental speech errors tend to respect syllable position (in their study, >75% of errors), this constraint is respected by only a minority of within-word errors in Arabic (<40%). This is not to say that syllable position has no influence on production processes in Arabic; between-word errors respect syllable position at much higher rates (>80%).

These studies suggest that although speakers from a variety of language backgrounds make use of both segmental and syllabic structure, linguistic experience shapes the structure of processing mechanisms that integrate these dimensions of phonological representations. Future empirical and theoretical work is clearly needed to understand the factors that underlie these differences (see O'Seaghdha et al., 2010).
are faster at detecting lexical stress at earlier positions in the word (Schiller, Jansma, Peters, & Levelt, 2006). Schiller (2006) finds similar latency effects in electrophysiological measures.

Although it is independently represented, lexical stress information is closely integrated with syllabic and segmental structure. Typically, discussions of phonological processing use the covert term "metrical structure" to encompass syllable structure and lexical stress (e.g., Levelt et al., 1999). This reflects the assumption that both aspects of structure are stored and retrieved in an integrated form. Consistent with this, the implicit priming paradigm of Meyer (1991) is sensitive to overlap in syllabic length and stress position (Roelofs & Meyer, 1998). Stress also interacts with segmental structure. Intersecting segments tend to occur in similar prosodic positions (Garrett, 1975). Such effects extend beyond lexical stress to include multi-word prosodic structures, such as intonational phrases (Croft, Au, & Harper, 2010).

**Lexical Tone**

Like lexical stress, lexical tone appears to have a functionally independent role within the production system. In languages with lexical tones, the segmental content of two syllables can be exchanged without disrupting the tonal pattern (Chen, 1999; Wan & Jaeger, 1998). Lexical tone information does not influence the implicit priming effects driven by syllabic and segmental overlap (Chen et al., 2002; O'Seaghdha et al., 2010). In monitoring inner speech, electrophysiological data suggest speakers access segmental information earlier than tonal information (Zhang & Damian, 2009). Current empirical data do not clearly indicate how this independent dimension of structure is integrated with other information within phonological processes.

**Interim Summary: Representational Structure in Phonological Processes**

Phonological processes involve the retrieval of several distinct dimensions of phonological structure, specifying information regarding segmental and syllabic structure and the presence and location of lexical stress and tone. Although these dimensions are independently represented, properties along each dimension are coordinated with one another within phonological processing to form coherent phonological structures. The processes by which retrieval and coordination occur, and how the structure of such processes is influenced by linguistic experience, are less well understood.

**Lexical Influences on Phonological Processes**

During phonological processes, complex phonological representations are retrieved and encoded based on input from lexical selection processes. Evidence from a variety of methodologies suggests that word-level factors influence these retrieval and encoding processes. This section examines how specific lexical factors affect the processes of phonological processes.

**Lexical Frequency and Age of Acquisition**

Speakers learn to retrieve the phonological forms of certain words earlier than others (age of acquisition); some words are retrieved more often than others (lexical frequency). Both of these aspects of target words influence phonological processing. Early acquired words are named faster (see Johnston & Barry, 2006, for a review) and more accurately (Kittredge, Dell, Verkuilen, & Schwartz, 2008). High-frequency targets are named faster (Jeschenik & Levelt, 1994) and more accurately (Kittredge et al., 2008). These reaction time effects are absent in delayed naming, suggesting the facilitation of high-frequency and early acquired words does not arise in postretrieval articulatory processes (Jeschenik & Levelt, 1994; Johnston & Barry, 2006). Data from patterns of acquired impairment provide further evidence that such effects arise specifically within phonological processes. With respect to errors, the facilitation of high-frequency targets and outcomes is found in the performance of individuals with deficits to phonological processes (in the context of intact semantic and phonetic processing; Goldrick et al., 2010; Kittredge et al., 2008); similarly, age of acquisition effects have been documented at this level of processing (Kittredge et al., 2008).

Theories have accounted for such effects by two different classes of mechanisms. Much of the available data fail to distinguish between these two possibilities (but see Knobel, Finklestein, & Caramazza, 2008, for simulation evidence in favor of the first account). One type of proposal assumes that variation in experience with different lexical items is encoded within the structure of phonological processes, affecting the strength or efficiency of processes by which phonological representations are retrieved (MacKay, 1987). If low-frequency/late-acquired words have weak connections to their associated phonological representations, phonological retrieval is slower and less accurate relative to high-frequency/early acquired words.

A second set of interactions in experience word-level representations. Evidence from a variety of methodologies suggests that word-level factors influence these retrieval and encoding processes. This section examines how specific lexical factors affect the processes of phonological processes.

**Syntactic and Semantic Targets**

Lexical selection can be sensitive to syntactic and semantic properties of target words (i.e., the same evidence that phonological process impairments have shown selective effects for nouns or verb processes distinguishes grammatical category (Caramazza, 2002). The contrasting impairment pattern, difficulty with specific grammatical categories whereas in writing relative to nouns), suggests that his deficit is sensitive to processing. Further evidence produced by the same data (e.g., "bird" → /pre- not limited to lexical and semantic selection processes. Given this finding, the deficits within semantic processes suggest that sentence processing is sensitive to a strong influence on semantic and retrieval processes.

A somewhat smaller body of evidence distinguishes between these semantic dimensions.
A second type of proposal assumes that variations in experience are reflected by properties of word-level representations themselves (e.g., resting activation levels, Stemberger, 1985; selection thresholds, Jescheniak & Levelt, 1994; time required for representations to accumulate activation, Miozzo & Caramazza, 2003; verification time for binding representations to previous representational levels, Redolfi, 1997). The varying strength of word-level representations could then influence the efficacy of retrieval of phonological representations. For example, if low-frequency words are less active than high-frequency words, they spread less activation to their associated phonological representations. The reduced activation of phonological representations leads to increased reaction times and higher error rates (see Dell, 1990, for discussion).

**Syntactic and Semantic Properties of Targets**

Lexical selection processes are well known to be sensitive to syntactic and semantic properties of target words (Garrett, 1975, et seq.). There is some evidence that these also exert an influence on phonological processes. Studies of acquired deficits have shown selective modality-specific deficits to noun or verb processing, suggesting phonological processes distinguish among items from different grammatical categories. For example, Rapp and Caramazza (2002) present an individual with contrasting impairments across each modality. He has difficulty with speaking nouns (relative to verbs), whereas in writing he has difficulty with verbs (relative to nouns). These contrasting impairments suggest that his deficit does not arise at an amodal level of processing. Furthermore, because many of the errors produced by this individual were nonwords (e.g., “bird” → /purd/), it is likely that his deficit is not limited to lexical selection but extends to phonological retrieval. Other studies have documented complementary patterns (e.g., preserved spoken noun production), showing that such effects are not likely due to differences in form across these categories (see Rapp & Caramazza, 2002, for a detailed review). The finding of selective, modality-specific impairments within the set of open class words suggests that sentence production processes may exert a strong influence on the structure of phonological retrieval processes.

A somewhat smaller body of work has examined distinctions between lexical categories based around semantic dimensions. Selective impairments to lexical categories (or selective sparing of particular categories) have been used to argue that these distinctions are reflected within the structure of phonological processes. Particular dissociations that have been documented include proper versus common names (see Semenza, 2009, for a review), numerals versus non-number words, and abstract versus concrete words (see Rapp & Goldrick, 2006, for a review). For example, Rodriguez and Lagano (2008) report the selective sparing of proper names (specifically, names of countries, in the context of a phonological processing deficit. Scmenza et al. (2007) report an Italian-speaking individual with an acquired deficit affecting vowels more than consonants, suggesting an impairment to phonological processes (see also Caramazza et al., 2000). This individual made no phonological errors with number words (Bencini et al., 2011). Bouchaud-Lévi and Dupoux (2003) also report spaced number word production in a French speaking individual with an acquired deficit to phonological processes. This individual also shows less impairment on names of days and months and abstract nouns and verbs, even when words across categories are matched for variables that influence phonological retrieval (lexical frequency, phoneme length, and syllable structure).

**Semantically Mediated Relationships between Words**

A large number of studies from a variety of different methodological approaches suggest that the phonological structures of words semantically related to the target (e.g., dog and cat for target cat) are activated during phonological processing (see Goldrick, 2006, for a review). The first source of evidence in support of this claim came from the mixed error effect, the observation that phonological errors are more likely to result in semantically related versus unrelated words (e.g., all else being equal, errors like cat→rat are more likely than cat→hat). This is found in errors in spontaneous speech (Dell & Reich, 1981), experimentally induced errors (Martin, Weisberg, & Saffran, 1989), and the
errors of individuals with deficits in phonological processes (Rapp & Goldrick, 2000). More recent chronometric studies have provided additional support for this claim. For example, Peterson and Savoy (1998) demonstrate facilitation of the phonological structure of near-synonyms of the target. Finally, examination of hemodynamic responses during picture-word interference tasks suggests that semantically related distractor words influence phonological processes. Brain regions associated with form-based processing in production (e.g., posterior superior temporal gyrus) are modulated by visually (de Zubicaray, Wilson, McMahon, & Muthiah, 2001) and auditorily (de Zubicaray & McMahon, 2009; but see Abel et al., 2009) presented semantically related distractor words.

These effects are not limited to categorically related words within a single language. Translation equivalents (semantically related words in another language of bilinguals) also produce phonological facilitation effects. Costa, Caramazza, and Sebastián-Galles (2000) find facilitation in picture naming of cognates, translation equivalents that overlap in form (e.g., gato—gato for a Catalan-Spanish bilingual). Colomé and Miozzo (2010) documented facilitation of phonologically related noncognate translation equivalents (e.g., Catalan armilla “vest”–Spanish ardilla “squirrel”). Within a single language, other meaning-based relationships result in the activation of phonological structure of non-target words. These include semantic associates (e.g., dance-ball; Cutting & Ferreira, 1999); alternate target labels at different levels of categorization (e.g., subordinate-level seagull when basic-level bird is the typical label for a picture; Jescheniak, Hanste, & Schriefers, 2005); and words predicted by a preceding sentence content (e.g., nun, primed by “The woman went to the convent to become a...”; Ferreira & Griffin, 2003). (n.b. Authors such as Ferreira & Griffin (2003) argue that some of these effects arise within lexical selection rather than phonological encoding processes.)

Considerations” by Dell, Nozari, & Oppenhein (for discussion). To allow these coactivated lexical representations to influence phonological retrieval, many theories have adopted a cascading activation mechanism (Peterson & Savoy, 1998). Instead of restricting phonological retrieval to a single selected representation, cascading activation allows all lexical representations to pass activation on to their associated phonological structures. It is important to note that a wide variety of data suggest that there are critical limitations on the strength of this cascading activation (Rapp & Goldrick, 2000). In many situations, the activation level of the phonological structure of semantically related lexical representations is too weak to significantly influence processing (for a review, see Goldrick, 2006). These restrictions have led some authors to argue that cascading activation is typically restricted to a small number of exceptional situations (e.g., synonymy; Levelt, Roelofs, & Meyer, 1999) and is dependent on the varying attentional demands of production tasks (Roelofs, 2008). Although it is likely that these specific proposals are too restrictive (Goldrick, 2006; Humphreys, Boyd, & Warriner, 2010), the nature and magnitude of constraints on cascading activation remains an open area of investigation.

Rather than relying solely on active spreading activation processes, these effects could also be attributed, at least in part, to the structure of lexical representations. In parallel distributed processing accounts of language production (e.g., Plaut & Shallice, 1993), explicit lexical/morphological representations are replaced by acquired intermediate representations that mediate representations that reflect the structure of multiple representational domains (i.e., semantics and phonology). Thus, instead of relying solely on spreading activation processes to produce co-activation, the acquired “lexical” representations of car and dog could encode their semantic similarity directly. When these distributed representations are provided as input to phonological retrieval, their overlapping structure automatically results in the coactivation of multiple phonological structures, producing the effects reviewed in the preceding section (see Plaut & Shallice, 1993, for discussion of related interactive effects in the context of reading impairments). One potential advantage of this perspective is linking the on-line co-activation of semantically related words and semantic categories. Such representations (see discussion of categories), impairments (e.g., spreading activation requires more representation to critical areas of proposal). A constraint between open area for...
words and the patterns of selective impairment to semantic categories reviewed in the preceding section. Such impairments could reflect damage to the representational structure shared by these related words (see Watson, Armstrong, & Plaut, 2012, for discussion of similar effects related to grammatical categories). It is unclear how such category-specific impairments could be accounted for by a spreading-activation mechanism. Of course, like pure spreading-activation based accounts, this perspective requires means to limit the influence of co-activated representations (see Rapp & Goldrick, 2000, for a critical assessment of the Plaut & Shallice, 1993, proposal). As little work has examined this, the contrast between these types of mechanisms remains an open area for research.

**Phonological Relationships between Words: Lexical Neighbors**

Complementing the work on semantically driven activation of non-target lexical representations, research from a variety of different paradigms has shown that phonologically related lexical representations are activated during phonological processing (see Goldrick, 2006, for a review). The first source of evidence for such activation came from speech error research. The lexical bias effect refers to the observation that phonological errors are more likely to result in strings that correspond to words than nonwords (e.g., all else being equal, errors like cat→hat are more likely than cat→hap). This is found in errors in spontaneous speech (Dell & Reich, 1981), experimental errors (Hartsuiker, Corley, & Marrisensen, 2005), and the errors of individuals with deficits to phonological processes (Best, 1996). Costa, Roelstraete, and Hartsuiker (2006) found that experimentally induced errors are biased to result in words in the nontarget language of a bilingual. When performing a task in Spanish, participants are more likely to make phonological errors that result in strings that correspond to Catalan words versus nonwords in Catalan (even though both strings are nonwords in Spanish). To account for these effects, spreading-activation based theories have assumed that activation spreads bidirectionally between phonological and lexical representations. This produces positive feedback loops that boost the activation of phonological representations corresponding to words versus nonwords, producing an advantage for the former representations (see Dell, 1986, for supporting simulation results).

Following research in visual word recognition (Landauer & Streeter, 1973), researchers have referred to these coactivated phonologically related lexical representations as neighbors. Dell and Gordon (2003; see also Chen & Mirman, 2012) used simulation results to argue that neighbors could facilitate phonological retrieval of target forms by enhancing the activation of the phonological structure they share with the target. Consistent with this, several studies have enhanced processing of words with more neighbors relative to those with fewer neighbors (see Goldrick et al., 2010, for a review). Picture-naming latencies are shorter for words with more versus fewer neighbors (Vitevitch, Armbruster, & Chu, 2004). Words with more versus fewer neighbors are less susceptible to spontaneous (Vitevitch, 1997) and experimentally induced speech errors (Vitevitch, 2002). Individuals with deficits to phonological processes make fewer errors on words with more versus fewer neighbors (Middleton & Schwartz, 2011). Finally, neuroimaging results suggest enhanced processing of words with more versus fewer neighbors in regions associated with phonological processing (Peramunage, Blumstein, Myers, Goldrick, & Baese-Berk, 2011).

The first section of this article argued that during phonological processes, multiple dimensions of phonological structure are retrieved. However, the bulk of research on neighbors has focused exclusively on segmental structure (defining neighbors as those words differing from the target by the addition, deletion, or substitution of a single segment). Goldrick et al. (2010) find that speech errors arising in phonological processes shared length with their corresponding target forms at a rate greater than predicted by segmental overlap alone, suggesting that multiple aspects of phonological structure contribute to the activation of neighbors.

Nonphonological factors have also been argued to modulate the activation of neighbors (see Goldrick et al., 2010, for a review). Studies of errors arising spontaneously (del Viso, Igoa, & García-Albea, 1991) in experimental error-induction tasks (Goldrick, Baker, Murphy, & Baese-Berk, 2011; but see Dell, 1990) and subsequent to impairments to phonological processes (Goldrick et al., 2010) suggest that phonological errors are biased to result in words with high versus low lexical frequency. Bais, Costa, and Carreira (2008) find that after controlling for the overall number of neighbors targets with more high-frequency neighbors exhibit greater facilitation than those with low-frequency neighbors. These effects are consistent with the mechanisms that result in effects of target frequency. If frequency influences the strength of connections between
lexical and phonological representations, it modulates bottom-up as well as top-down activation flow. Similarly, if frequency modulates the strength of lexical representations, it affects the ability to influence error outcomes or target phonological processing.

Syntactic category also seems to influence the activation of neighbors. Phonological errors are biased to result in words that share syntactic category with the target (spontaneous errors, Harley & MacAndrew, 2001; subsequent to phonological processing impairments, Goldrick et al., 2010). This suggests that the syntactic representations and processes that influence lexical retrieval also exert an influence on phonological processes. This could be accounted for within a cascading activation framework. If syntactic representations boost the activation of nontarget words with the target-appropriate grammatical category (e.g., Dall et al., 1997), this enhanced activation could cascade and enhance the activation of associated phonological representations (see Goldrick & Rapp, 2002, for supporting simulation results).

Phonological Processes: Bridging Lexical and Phonetic Representations

Since the seminal work of Garrett (1975), drawing nearly exclusively on patterns of errors in the spontaneous speech of monolingual speakers of Germanic languages, research into phonological processes has noticeably diversified. Research in this area now draws on experimentally induced speech errors and chronometric and neurophysiological measures; it considers the performance of speakers from a (more) diverse array of languages, multilingual speakers, and individuals with acquired cognitive impairments.

These new techniques and populations have confirmed some of the original proposals based on speech error data. These findings support the claim that phonological processes involve the retrieval of relatively abstract phonological representations; these specify lexical stress, syllabic, and segmental structure, but lack featural information. Chronometric and electrophysiological data have extended and enriched the understanding of phonological processes by providing insight into the temporal structure of these processes, supporting incrementality in at least some aspects of retrieval and encoding. Consideration of data from a more diverse array of languages has revealed the role of lexical tone at this level of processing.

Other results have highlighted the limitations of early work on phonological processing. Cross-linguistic research has revealed that apparently fixed features of the processing system are highly influenced by the linguistic environment. In particular, there is considerable variation in the degree to which syllabic and segmental representations are integrated during processing. Additional error-based, chronometric, and neurophysiological research in monolinguals, bilinguals, and individuals with aphasia has documented substantial interactions between lexical and phonological processes in speech production. The strong constraints on such interactions are the likely source of disagreements between this research and earlier work. Because there are many situations under which significant lexical influences are not observed during phonological processes, the observation of such interactive effects requires consideration of a wide range of processing conditions.

A clear avenue for future investigations concerns the internal structure of phonological processes. Although many theories have distinguished retrieval of independent dimensions of structure (e.g., segmental, syllabic) from the encoding of an integrated phonological representation, the degree to which these two functions are subsumed by independent cognitive processes is unclear. Assuming they are independent, there is considerable disagreement regarding the nature of each aspect of processing (e.g., whether one or both of these processes are incremental). A challenge for future work is to more precisely delineate the empirical contrasts between these theoretical perspectives.

Although there are many issues that remain unresolved, recent research has clearly shown that phonological processes cannot be considered in isolation, either from other cognitive processes within the individual or from the linguistic environment in which the speaker is embedded. However, the substantial empirical base for such effects has not yet been matched by theoretical accounts that allow one to predict the nature and extent of such effects. The challenge for future work in this area is to understand the principles that allow these processes to shape representations and processes within phonological processing in speech production.

Author Note

Thanks to Simon Fischer-Baum and Jordana Heller for helpful comments on the manuscript. Preparation of this manuscript was supported by National Science Foundation Grant BCS0846147. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

Notes

1. These posterior with phonologic imaging studies.
2. In addition to activity, activity in left hemisphere is modulated by lexic realism.
4. Phonemic representation between Phonological Processes.
5. Because the existence of the segmental term "geometric units as large as" is not at issue, Goldrick and Pauly, 1999, in the geometry of literature, provides Brownman.
6. Coyle et al. (2002) identified the effect in inner Oppenheim and Goldrick, and argues that Coyle phonemes simultaneously the claims of Oppenheim and Brownman.
7. Damian and Brownman are due to orthography, priming is disrupted. However, subsequent Ziegler, 2007; Roeicin, or cing effects are used that an explicit
8. Two concepts relevant to influence trajectory (reflecting influence over the region of spread; number of experts). Although conditioned age of acquisition at make independent contribution, see Bonin, Barra, Mermillod, and Ferrand.
9. Some authors (e.g., "Speaking to monitoring mechanisms" in discussion of such predictions.

References


PHONOLOGICAL PROCESSING
the author and do not necessarily reflect the views of the National Science Foundation.

Notes
1. These posterior regions have been independently associated with phonologic retrieval by meta-analyses of functional imaging studies (Indefrey & Levelt, 2000, 2004).
2. In addition to being modulated by phonetic complexity, activity in these frontal regions has also been shown to be modulated by lexical factors (lexical frequency: Wilson et al., 2009; lexical neighborhood density: Peramunage, Blumstein, Myers, Goldrick, & Bao-Bo, 2011). Such effects are consistent with feed-forward interactions (e.g., cascaded activation) between phonologic and phonetic processes (see Phonetic Processing by Bachwald for further discussion).
3. Because the existing evidence does not provide clear evidence in favor of a particular representational type, the term “segment” is intended to encompass representational units as large as traditional phonologic segments (e.g., inton units. Goldsmith, 1990; root nodes. Archangeli & Pulleyblank, 1994) and smaller subgroups (e.g., nodes in feature geometry. Sag, 1986: phrasing relations between gestures. Brown & Goldstein, 1989).
4. Coyle et al. (2011) report a significant phoneme similarity effect in inner speech errors; they argue this contradicts Oppenheimer and Dell’s (2008) claim. Oppenheimer (2012) argues that Coyle et al. did find an attenuation of phoneme similarity effects in inner speech, consistent with the claim of Oppenheimer and Dell (2010).
5. Damian and Bowers (2003) argued that this effect could arise due to orthographic influences in this paradigm (i.e., priming is disrupted because a and b are different letters). However, subsequent studies (Alario, Perre, Canel, & Ziegler, 2007; Rochee, 2006) showed that such orthographic influences are unreliable and appear to be limited to tasks that have an explicit orthographic component.
6. Two concepts related to age of acquisition have also been argued to influence lexical access in production: frequency and age of acquisition (reflecting shifts in the distribution of word occurrence over the lifespan) and cumulative frequency (total number of exposures to a lexical item over the lifespan). Although correlational, these measures are distinct from both age of acquisition and frequency; they have been argued to make independent contributions to production (for discussion, see Bonin, Barry, Merv & Chalant, 2004; Bonin, Merv, Mervland, Ferrand, & Barry, 2009; Peres, 2007).
7. Some authors (e.g., Levelt, 1999) have attributed such effects to monitoring processes (perhaps based on lexical constraint mechanisms; see Harnualer, 2005, for critical discussion of such proposals).

References


Perez, M. (2007). Age of acquisition predicts the main factor in picture naming when cumulative word frequency and frequency trajectory are controlled. Quarterly Journal of Experimental Psychology, 60, 32-42.


Goldrick


---

**Abstract**

Successful linguistic planning takes into account context-specific factors that affect the way an episode affects language production. This chapter addresses the role of language planning in the context of language production.

**Key Words**

Language planning, language production, context-specific factors.