3 Lexical priming

Associative, semantic, and thematic influences on word recognition

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Lexical priming occurs when the response to a target word varies systematically as a function of the preceding linguistic context. Typically, the target word elicits a faster response after a context that is related than after an unrelated context. For example, following the related prime word "cat", the target word "mouse" tends to elicit faster and/or more accurate responses. Although much of the research has employed single word primes (e.g., Meyer and Schvaneveldt, 1971), as in this example, more complex contexts such as sentence frames and discourse contexts can also induce lexical priming (e.g., Camblin et al., 2007; Hess et al., 1995). This chapter provides an overview of the many measures, models, and types of lexical priming. It also summarizes individual differences in lexical priming across the lifespan and among healthy and cognitively impaired populations.

Lexical priming is an extremely pervasive phenomenon in visual word recognition. Because words rarely occur in isolation, they are nearly always subject to the many potential influences of preceding words. Understanding lexical priming is thus paramount for understanding word recognition. Lexical priming can also be used to discriminate between models of cognition more generally. For example, the connectionist (e.g., Rogers and McClelland, 2004), rational (e.g., Anderson and Lebiere, 1998), and embodied (e.g., Barsalou, 2008) approaches to cognition all attempt to explain lexical priming in different ways. Research on lexical priming therefore can impact psychology beyond word recognition.

In addition to its theoretical implications, lexical priming also has important implications for many practical areas of study, such as the development of reading skill (e.g., Andrews, 2008; Michael, 2009; Nation and Snowling, 1999) and conceptual organization (Perraudin and Mounoud, 2009), and the understanding of disorders such as schizophrenia (e.g., Kostova et al., 2005; Lecardeur et al., 2007) and Alzheimer's disease (e.g., Giffard et al., 2009). Knowledge of the recent developments in lexical priming may also enable researchers to further investigate topics of interest in education, gerontology, and other related fields. Hence, we present an overview of the methods and models of lexical priming, and we discuss some of the prevailing questions within the field. In doing so, we will emphasize recent research and newer methods that have addressed some of the fundamental questions raised in prior reviews of lexical priming (e.g., Hutchison, 2003; Lucas, 2000; McNamara, 2005; Neely, 1991).

Measures of lexical priming

In this section we briefly describe several measures of lexical priming, including the lexical decision, word naming, perceptual identification, and semantic decision tasks, as well as more recent eye-tracking and neuroimaging methods. First, however, we consider the most appropriate control or *baseline condition* against which lexical priming should be compared. This choice of a baseline has proven somewhat problematic regardless of which task one employs, as unfortunately there is no consensus about what baseline is most appropriate. Researchers have used a number of different baseline primes, including a string of neutral symbols such as asterisks or Xs, a word like "blank" or "ready", a blank pause, a nonword like "brid", and a prime word that is unrelated to the target. One problem in using a repeated baseline is that participants may become habituated to these repeated primes during the course of the experiment and consequently may attend less to both the repeated neutral primes and the related primes (Jonides and Mack, 1984; McNamara, 2005). McNamara suggests using pronounceable nonwords (e.g., "brid"), though he cautions that the increased latencies for processing these nonword primes may carry over to artificially longer target latencies. Alternatively, Bodner et al. (2006) found that a 45-ms blank pause baseline eliminated the tendency for slower responses on baseline trials than on unrelated-prime trials. Several behavioral studies have demonstrated that lexical priming is robust across the various baseline measures (e.g., Bodner et al., 2006; Bodner and Masson, 2001; Estes and Jones, 2009; Jones, 2010) up to 1000 ms. However, at longer SOAs (> 1000 ms), nonword repetitive baselines have been found to artificially inflate priming effects (de Groot et al., 1982; Jones, 2011, in press; Jonides and Mack, 1984), and thus should be avoided or supplemented with other baseline primes. The choice of baseline prime may be even more important in ERP studies. Unrelated word primes tend to maximize the N400 effect (described below), whereas a repeated neutral word like "blank" may produce an N400 that is similar to a related prime (Dien et al., 2006). Overall, the consensus is that there is no truly neutral prime (Bodner et al., 2006; Jonides and Mack, 1984; McNamara, 2005; Neely, 1991). The best option for purposes of convergent validity is to use more than one type of baseline prime, either within or across experiments.

Lexical decision

The most common measure of lexical priming is the lexical decision task (LDT), whereby participants decide whether a given letter string is a real word (e.g., "bird") or a nonword (e.g., "brid"). There are several variations of the LDT. In the *continuous LDT* (a.k.a. *sequential* or *single LDT*), participants respond to each individually presented prime and target letter string. In the *standard LDT*, primes and targets are presented individually, and participants respond only to the target. In the *double LDT*, prime and target strings are displayed simultaneously, and participants indicate by a single response whether both are real words. Priming is observed as a difference in response times or error rates following a related prime relative to a baseline prime. For example, in their seminal study, Meyer and Schvaneveldt (1971) found that responses in a double LDT were 80 ms faster for related pairs such as "NURSE – DOCTOR" than for unrelated pairs such as "BREAD – DOCTOR". The primary advantages of the LDT are its minimal technical requirements and its ease of administration.

To administer a LDT, the researcher must specify a number of procedural parameters. First, one must choose the prime duration and the *stimulus onset asynchrony* (SOA), which is the delay between prime and target onset. The prime duration is important because it determines whether the prime can be processed consciously (i.e., generally at durations longer than 30 ms), or only unconsciously (i.e., generally 30 ms or less, followed by a visual mask such as "#######"). The SOA is important because it determines the extent to which the prime may be processed prior to target presentation (i.e., prospectively), with longer SOAs allowing more prospective processing. The researcher must also specify a number of properties of the nonword trials. One must determine the percentage of trials for which the target is a nonword. Although this is typically 50%, this can be manipulated to bias participants toward either "word" responses (e.g., only 25% nonword targets) or nonword responses (e.g., 75% nonword targets). The researcher must also determine whether the nonwords are pronounceable (e.g., "brid") or unpronounceable (e.g., "bdri"), which affects how deeply the targets are processed. One must additionally determine the *relatedness proportion* (RP), which is the proportion of trials on which the prime and target are related (for a review, see Hutchison, 2007). This factor is often used to test whether an effect is strategic or automatic. If an effect is under participants' strategic control, then presumably it should occur under conditions in which the prime and target are likely to be related (i.e., high RP) but should be attenuated when the prime and target are unlikely to be related (i.e., low RP). Thus, the observation of an RP effect provides evidence of strategic processing. A potentially more important but often overlooked factor is the *nonword ratio* (NR), which is the probability that the target is a nonword given that it is unrelated to the prime (Neely and Keefe, 1989). Although RP and NR are conceptually related and often confounded, they can differentially affect lexical decisions (Neely et al., 1989).

Word naming (reading aloud)

In the word naming task, participants simply read aloud as quickly as possible the given word. The onset and accuracy of the vocal response typically serve as the dependent measures, though a number of other measures are also available (e.g., duration, pitch, jitter, shimmer; see Kent and Read, 2002). As in the LDT, lexical priming is observed as a difference in response times or error rates following a related prime relative to a baseline prime. Word naming is higher than the LDT in ecological validity (because the task only entails reading), it is more efficient (because nonword trials are unnecessary), it is less likely to exhibit a speed–accuracy tradeoff (because errors are less common), and it is simpler to administer (because the RP and NR factors do not apply). The primary disadvantage of the word naming task is that analysis of participants' sound files may be cumbersome. The word naming task is less susceptible than the LDT to strategic processing, so word naming provides a stronger test of automaticity, whereas the LDT may be necessary to observe strategic effects (Balota and Chumbley, 1984). Similarly, because semantic effects tend to be smaller in word naming than in lexical decisions, the LDT may be more effective for comparing different types of priming.

Perceptual identification

The perceptual identification task entails very brief presentation of target words, which participants attempt to identify. For example, the target word "mouse" might appear for only 30 ms. Several response types are possible. For instance, participants could be asked to report the presented word, to indicate whether the presented letter string is a word or a nonword, or to choose the presented word from several options (e.g., "mouse or house?"). The dependent measure here is accuracy, and lexical priming is observed as a difference in accuracy following a related prime relative to a baseline prime. As in the LDT and word naming, the duration of the prime word and the SOA must be determined by the researcher, but note that the prime is typically presented for a longer duration (e.g., 500 ms). The target duration is typically between 15 and 45 ms, so as to avoid floor and ceiling accuracy rates. Moreover, perception of the target is further controlled by overlaying a visual mask (e.g., #####), which prevents continued inspection of the perceptual representation of the target in iconic memory (Masson and MacLeod, 1992; for a review see Van den Bussche et al., 2009). Target accuracies in this perceptual identification paradigm typically are in the 60–80% range, with reliably higher accuracies for related than unrelated prime-target pairs.

Semantic decision

In a semantic decision task, participants make some semantic judgment of a target word. For example, participants may be asked to indicate the semantic category of the target (e.g., "animal or object?", Spuryt et al., 2009), or to verify a particular semantic feature (e.g., "Does the word refer to something that is alive?", Hare et al., 2009). Affirmative "yes" responses are faster for targets following primes that share the semantic feature of interest (e.g., animals). This task can take the form of a continuous procedure (in which decisions are made for both prime and target), a naming procedure (in which the participant verbally responds with the correct semantic decision; "animal" or "object"; Spuryt et al., 2009), or a standard procedure (in which only the targets are evaluated; Hare et al., 2009). Semantic decision tasks offer a couple of advantages over the LDT. First, a semantic decision task requires participants to more closely attend to a particular semantic dimension (e.g., animacy, valence, concreteness), which increases the activation of the concept's semantic representation. In turn, this heightened activation of the concept's semantic representation may facilitate priming across long SOAs and intervening items between prime and target (Becker et al., 1997). Indeed, long-term priming across 0, 4, and 8 intervening items was found for highly similar pairs in a semantic decision task but not in a LDT (Becker et al., 1997). Second, the filler items can be related but still require a "no" response (e.g., TABLE → CHAIR for "Does the word refer to something that is alive?"). Consequently, prime-target relatedness does not become a cue for a "yes" or "no" response, thereby hindering a relatedness checking strategy (Hare et al., 2009).

Eye tracking

Eye tracking, whereby participants' eye movements and fixations are recorded in relation to visual stimuli, is a rich alternative for assessing lexical priming (Ledoux et al., 2006; Odekar et al., 2009). It offers a number of methodological advantages, including high ecological validity and continuous measurement without disruptive behavioral responses such as button presses or vocal responses. Eye tracking also provides a wealth of data, including multiple measures of the latency, location, and duration of fixations, as well as the trajectory and speed of eye movements. One paradigm for measuring lexical priming via eye tracking is to follow a prime word with an array of target words, one of which is semantically related to the prime. For instance, "king" might be followed by "monkey", "candle", "bicycle", and "queen", and lexical priming would be manifest as an earlier and/or longer fixation on the semantically related word "queen" (e.g., Meyer and Federmeier, 2008). Another paradigm is to present a target word in the presence of a context, such as a sentence or prime word, and to observe eye movements to and fixations on the context and/or target words (e.g., Camblin et al., 2007; Morris, 1994; Rayner et al., 2004). Such eye tracking measures of lexical priming correlate with standard behavioral measures of priming (Folk and Morris, 1995; Odekar et al., 2009).

Neuroimaging

The rapid growth of cognitive neuroscience has provided researchers with a valuable tool for studying the temporal and spatial patterns of brain activity during lexical priming. These neural measures have the potential to reveal effects of lexical priming that may not be detected via standard behavioral methods. For instance, such measures can provide additional information regarding the time course of lexical priming and/or the underlying neural regions involved in lexical priming (e.g., Rossell et al., 2003). Moreover, lexical priming may involve some observable neural processes that ultimately produce no observable behavioral effects. Event-related potential (ERP) priming studies provide information on the valence (positive or negative) and timing of neural voltages recorded as wave amplitudes by an electroencephalogram (EEG). Functional magnetic resonance imaging (fMRI) indirectly measures cerebral blood flow via the BOLD (blood-oxygen level dependent) response and provides better spatial resolution than ERP.

Of these methods, the N400 ERP component has been the most studied. The N400 refers to larger negative amplitudes approximately 400 ms following stimulus onset for items that are semantically incongruent with the previous context than for items that are semantically congruent (Chwilla et al., 1998, 2000). Though the N400 is thought to reflect controlled processes (e.g., semantic matching, lexical integration), some have argued that it may also reflect uncontrolled processes such as automatic spreading activation (see Franklin et al., 2007). Studies using fMRI may also differentiate between various mechanisms of priming (e.g., Franklin et al., 2007; Sass et al., 2009) and representational codes (e.g., conceptual versus perceptual; Giesbrecht et al., 2004).

Models of lexical priming

Models of lexical priming traditionally are distinguished along two main theoretical dimensions: Priming may occur prospectively or retrospectively, and it may be controllable (a.k.a. strategic) or automatic. *Prospective* models claim that the prime word pre-activates the target word, thereby speeding its recognition. *Retrospective* models posit that the prime and target words are considered together, and if they are congruent in any way (e.g., associated, similar, familiar), then the target elicits a fast response. For example, the prime "cat" could pre-activate the target "mouse" before the target is even presented (i.e., prospectively), or "cat" and "mouse" could be considered together after the target is presented (i.e., retrospectively). *Strategic* models assert that individuals can strategically control how the target word is processed. For example, one can opt to compare "cat" and "mouse" or not, depending on one's current goals and the task conditions. *Automatic* models, in contrast, suppose that individuals are unable to intentionally modulate processing of the target word. That is, "cat" and "mouse" are compared regardless of one's intention.

These two theoretical dimensions – direction (prospective or retrospective) and controllability (automatic or strategic) of priming – are orthogonal, thus yielding four basic classes of models (see Table 3.1). To illustrate, the spreading activation model (described below) posits that priming occurs prospectively and

Table 3.1 Theoretical dimensions and major models of lexical priming

Direction	*Control*	
	Automatic	*Strategic*
Prospective	Spreading activation ACT* Thematic integration	Expectancy
Retrospective	ACT*	Semantic matching Compound cue Episodic retrieval

automatically, whereas the semantic matching model claims that priming acts retrospectively and strategically (Hutchison, 2002; Jones, 2010). Several other computational and mathematical models of word recognition are addressed in detail in Volume 1 (Forster; Gomez; Sibley and Kello), and therefore we will present only briefly some of the major models as they relate to the various types of lexical priming.

Spreading activation

According to the spreading activation model, concepts are represented as nodes in a semantic network. Perception or memory of a target word activates its semantic representation, and that activation spreads very quickly (≈1 ms per link) to neighboring nodes representing related concepts. Activation decays with the distance it travels in the semantic network, and when attention to a source node (e.g., the prime) ceases, the pattern of activation emanating from that node rapidly decays. Alternative models of spreading activation explain lexical priming in different ways. Collins and Loftus (1975) attribute lexical priming to the prime word causing a spread of activation to the target concept, thereby pre-activating the target word. Anderson's (1983) ACT* model describes lexical priming in terms of *reverberation*, in which activation can spread back from a target node to its source node and then back from the source node to the target until an asymptotic level of activation is reached. Thus, the ACT* model predicts that "asymptotic target activation is determined by associations in the forward and backward directions" (McNamara, 1992a, p. 1177). This model thus accommodates retrospective, in addition to prospective, explanations of lexical priming (see Table 3.1). Priming effects occurring in tasks that do not permit an awareness of prime-target pairing (e.g., naming, continuous LDT) are generally considered to indicate automatic spreading activation.

Expectancy

During a lexical priming task people may form predictions about what words will follow a given prime. This "expectancy set" can vary in size based in large part on the consistency of relations used within a list. That is, if just one type of relation (e.g., antonyms) is used within the list, participants should be better able to predict the related word that will follow a prime. Moreover, primes (e.g., DAY) that have only one or two strongly associated targets (e.g., NIGHT) should yield a smaller expectancy set. The generation of an expectancy set appears to be a controlled process, as it is subject to the RP effect (Bodner and Masson, 2003; Hutchison, 2002). Thus, the generation of an expectancy set is prospective, meaning that target activation increases *prior to* its actual presentation (see Table 3.1). The formation of an expectancy set is thought to take approximately 300 ms to fully develop (Becker, 1980; den Heyer et al., 1985; Hutchison et al., 2001; Neely, 1991; Perea and Rosa, 2002). Expectancy generation may account for lexical priming found at intermediate and longer SOAs (up to 2000 ms) for highly associated items. However, it may be difficult to maintain the generated expectancy set in working memory over very long SOAs (>2000 ms). Further research is needed to test the influence of working memory in the maintenance of an expectancy set across a long SOA and/or intervening items.

Semantic matching

Semantic matching refers to a search for a meaningful relation between prime and target (Jones, 2010; Neely, 1977; Neely et al., 1989). In a LDT, for instance, participants may check for a relation between prime and target words following presentation of the target. If the prime and target are indeed related, then the target must be a word, since words are rarely related to nonwords. So participants are biased to respond that the stimulus is a word if a semantic relation is present and to respond that it is a nonword if a relation is not present. Thus, as characterized in Table 3.1, semantic matching is a retrospective process that can occur only after target presentation. It is also a controlled process that varies across RP manipulations (Estes and Jones, 2009).

Episodic retrieval

In lexical priming studies, a target word may elicit retrieval of the prime. If the target is in any way related to or consistent with the prime, then its recognition will be facilitated (Bodner and Masson, 2001, 2003). Thus, episodic retrieval is conceptually similar to semantic matching. It is also similar to the compound cue model (McKoon and Ratcliff, 1992; Ratcliff and McKoon, 1988), which attributes lexical priming to the retrieval of the prime-target compound from long-term memory. All three of these processes (i.e., semantic matching, episodic retrieval, and compound cue) act retrospectively to interpret the target in the context of the prime and assume priming to be controllable.

Thematic integration

Thematic integration entails the inference of a plausible thematic relation and the assignment of concepts to complementary functional roles in that theme (Coolen et al., 1991; Estes et al., 2011a; Estes and Jones, 2008, 2009; Wisniewski, 1997). For example, a "winter holiday" is a holiday *during* the winter, and a "chocolate bar" is a bar *composed of* chocolate. By a thematic integration model, lexical priming occurs when the target word is thematically integrated with the prime. That is, if the target word (e.g., "holiday") can perform a different functional role in the same theme (e.g., X *during* Y) as the prime word (e.g., "winter"), then target recognition is facilitated. Although the thematic integration model of lexical priming has not yet been thoroughly researched, some evidence indicates that thematic integration is beyond strategic control, as integrative priming is insensitive to manipulations of RP (Estes and Jones, 2009). That is, thematic integration occurs even among lists in which few of the words can plausibly be integrated.

Other recent work in our laboratories suggests that thematic integration also occurs prospectively. In particular, we have found recently that integrative priming is obtained in the masked perceptual identification task in which target words were presented for only 20 ms. This very brief target presentation precludes retrospective processing, yet targets were identified more accurately when they could be easily integrated with the prime word than when they could not be integrated with the prime (Estes et al., 2011b). Thus, preliminary evidence suggests that thematic integration occurs prospectively and automatically (see Table 3.1).

Types of lexical priming

Traditionally studies on lexical priming classified their stimuli as either associative or semantic (for reviews see Lucas, 2000, McNamara, 2005, and Hutchison, 2003). Semantic relations generally refer to any feature-based relationship between two concepts such as a category and exemplar (e.g., FRUIT and PEAR), category co-members (e.g., CAT and DOG), or instrument and object (e.g., BROOM and FLOOR). In contrast, associative relations are defined by the free-association task (described below) and are therefore assumed to reflect word use more than word meaning (Thompson-Schill et al., 1998). In addition to associative and semantic priming, much recent research has examined thematic priming. Below we review the evidence concerning all three of these main sources of priming, as well as mediated priming.

Associative priming

Lexical association has been defined most frequently as the proportion of participants in a free association task who produce a specific target word (e.g., DOG) in response to a given cue word (e.g., CAT). The creation of online databases such as the University of South Florida Free Association Norms (Nelson et al., 1998), which are based on samples of approximately 100 participants per cue word, have enabled researchers to easily control or manipulate association strengths for their stimuli. Many recent studies have adopted Nelson and colleagues' (1998) descriptive categories of association strengths: strong (>0.20), moderate (between 0.10 and 0.20), weak (between 0.01 and 0.10), and unassociated (< 0.01).

More recently, a number of other valid indicators of association have been found to produce reliable priming effects including whether the associate is the primary or non-primary response to a cue (Anaki and Henik, 2003), the number of associates produced for a given cue (Ron-Kaplan and Henik, 2007), and the connectivity among the associates (Nelson et al., 1993; Wible et al., 2006). For example, the primary (most frequently provided) associate for a given cue may be strong (e.g., BROTH → SOUP, forward association strength = 0.806; values taken from Nelson et al., 1998) or weak (e.g., CHICKEN → SOUP, 0.092) in association strength. Anaki and Henik found that both strong and weak primary associates produce comparable priming effects that are larger than non-primary associates.

Moreover, co-occurrence of two items may also influence priming. Co-occurrence may be measured as the local co-occurrence of any two items as they appear together in a particular order in text. For instance, the number of Google hits for a word pair presented within quotation marks (e.g., "chicken soup") serves as a measure of local co-occurrence frequency in everyday language and is highly correlated with familiarity (Wisniewski and Murphy, 2005). Hence, Google can be used to assess this type of local co-occurrence (e.g., Estes and Jones, 2009; Jones, 2010). The British National Corpus and the American National Corpus are both searchable databases that can also be used for assessing local co-occurrence. Global co-occurrence is the frequency with which two words appear within the same or similar written text. For example, Latent Semantic Analysis cosines (*LSA*; Landauer et al., 1998) provide a very broad measure of global co-occurrence. However, LSA does not take word order into account (CHICKEN SOUP would have the same LSA value as SOUP CHICKEN). The BEAGLE model Jones and Mewhort, 2007) represents both global co-occurrence and word order. Other sources, such as the Usenet database (Lund and Burgess, 1996; see also Shaoul and Westbury, 2006) and the WordMine2 database (Durda and Buchanan, 2006), can provide both local and global measures of co-occurrence. Given the impact of co-occurrence in lexical priming, it is important to assess this factor when examining the differences in lexical priming across various relation types or task conditions.

In addition to association strength and frequency of co-occurrence, the type of relation may also influence lexical priming. Since the first lexical priming study (Meyer and Schvaneveldt, 1971), the last 40 years of research have demonstrated robust lexical priming between associated concepts sharing many different types of relations including antonyms (DAY NIGHT), synonyms (BOAT SHIP), attributes (ZEBRA STRIPES) and highly similar (APPLE PEAR) or less similar (GRAPE WATERMELON) category coordinates, to name just a few. Among these, antonyms were the most frequently occurring relation in one set of norms for college-aged adults (see Hutchison, 2003, Table 1). Behavioral studies have found similar priming effects among antonyms, synonyms, and category coordinates that were either associated (e.g., HATE LOVE, HOUSE HOME, TABLE CHAIR) or unassociated (e.g., CRAZY SANE, SHOP STORE, SILK COTTON; Perea and Rosa, 2002; Williams, 1996). However, as we will discuss, ERP studies have found subtle differences among different types of associated items (see Franklin et al., 2007).

Recent research has expanded the investigation of lexical priming to several other types of relations including phrasal associates (WIND MILL) and locative (KITCHEN TABLE), compositional (GLASS TABLE), and event or script (PARTY MUSIC) relations. McRae and Boisvert (1998, p. 569) noted that "prime-target pairs often depict a number of types of relations and include primes from various grammatical and semantic categories." They noted that investigations of different types of relations with a broad category (e.g., unassociated semantically related items) would entail empirical work to norm the items to ensure that they exemplified the relation type. Hutchison (2003) further argued that more experimentation was needed to explore the priming effects of many of these less studied relations, such as phrasal associates and script relations.

Semantic priming

Several studies (e.g., Estes and Jones, 2009; Moss et al., 1995; Perea and Rosa, 2002) have found processing differences between associative and semantic priming, which suggests that different theoretical models may be required to explain these different processes.

Do associative and pure semantic priming reflect different processes?

The time course of activation (i.e., the extent of facilitation) differs between associative and semantic relations. At short (i.e., <300 ms) or medium (approximately 300–800 ms) SOAs, both associatively and semantically related primes facilitate target responses. But at longer SOAs (i.e., typically ≥1000 ms), semantic priming is reduced or eliminated, whereas associative priming remains stable or increases. For example, Estes and Jones (2009) found equivalent priming effects at a 500-ms SOA in a standard LDT between pure semantic relations (FOX → DOG) and associatively related items (BONE → DOG). For the semantic items, activation decreased only slightly at a 1500-ms SOA, but was eliminated at a 2500-ms SOA. In contrast, for the associative items, the priming effect increased at a 2000-ms SOA (see also den Heyer et al., 1985; Perea and Rosa, 2002).

Such behavioral studies suggest that pure semantic priming is a fast-acting process, which decays at longer SOAs (Van den Bussche et al., 2009). In contrast, associative priming is thought to reflect primarily spreading activation when occurring in standard LDTs at short SOAs (<300 ms) and in continuous LDTs, and expectancy when occurring at longer SOAs. The type of associative relation may determine the processing mechanism. For example, expectancy sets are smaller for antonyms than for category coordinates (Chwilla et al., Kolk, Mulder, 2000), and thus antonyms may be processed via either spreading activation or expectancy.

ERP studies also suggest a difference between the processing involved in associative vs semantic relations (Rhodes and Donaldson, 2008; for review see Franklin et al., 2007). In a double LDT (Roehm et al., 2007), antonyms (BLACK WHITE) had faster response times and lower N400 amplitudes than related category co-members (BLACK YELLOW), which in turn were faster and lower in N400 amplitudes than unrelated items (BLACK NICE). The difference may lie in the exact time window of the N400 amplitude. Semantically similar items (SOFA BED) exhibited an N400 effect at an earlier time-window (250–375 ms) but not in a later one (Koivisto and Revonsuo, 2001). In contrast, lexically associated compounds (WIND MILL) exhibited an N400 effect in both this earlier and a later time window (375–500 ms), which likely reflects a semantic matching or expectancy process rather than automatic spreading activation.

Is association required for semantic priming?

The answer to this question depends on several factors including the similarity of the prime and target and the type of task. Moss and colleagues (1995) found reliable priming for associated (DOG → CAT) but not for unassociated (PIG → HORSE) category coordinates (see also Shelton and Martin, 1992). Yet McRae and Boisvert (1998) noted that the stimuli used in Shelton and Martin (1992) and Moss et al. (1995) were lacking in similarity (e.g., DUCK COW). To assess the importance of similarity in semantic priming, McRae and Boisvert tested whether highly similar (GOOSE → TURKEY) and less similar (ROBIN → TURKEY) category co-members would yield reliable priming effects at both short (250 ms) and long (750 ms) SOAs. Using a standard LDT, they found reliable priming at both SOAs for the highly similar items, but only at the long SOA for the less similar items. These studies, along with our findings of reliable priming for similar categorical coordinates at a short SOA of 100 ms (Estes and Jones, 2009, Experiment 2), suggest that similarity between prime and target is a critical factor in obtaining reliable priming at short SOAs (see also Bueno and Frenck-Mestre, 2008, for a similar result using a masked priming paradigm).

Thematic priming

In addition to the *featural similarity* and *taxonomic* information typically investigated in studies of semantic priming, many other aspects of a concept's meaning are activated based on one's world knowledge about a concept (Estes and Jones, 2009; Hare et al., 2009; Moss et al., 1995) or even one's recent exposure to an incidental association (i.e., words that had appeared within a recently presented sentence; Prior and Bentin, 2008). Such world knowledge relations include: *locative* (BEACH HOUSE); *instrumental* (REALTOR HOUSE); *schematic* (a.k.a., *script* or *event-based*, RENTAL HOUSE); and *compositional* (BRICK HOUSE) among many others.

Theoretically, integration (either relational or situational) has been proposed to explain this type of priming and thus distinguishes it from the more traditional taxonomic/similarity-based semantic priming. For some of these relations (e.g., *locative, compositional*), integration occurs upon target presentation via the inference of a relation (a BEACH HOUSE is a HOUSE that is *located* on a BEACH). Relational integration then entails the linking of prime and target into one plausible entity. To assess the extent of relational integration between prime and target, participants rate the extent to which the prime-target pairs "could be linked together to produce a sensible phrase" (Estes and Jones, 2009, p. 116). In contrast, for other relations (e.g., *script, instrumental)*, the integration has occurred previously via the pairing of prime and target in one's experiences and/or vicariously by exposure to this pairing in text or other media. Unlike relational integration, thematic and instrumental priming do not necessarily entail the merging of two concepts into a single entity. Rather the concepts are connected via an action verb in the case of instrumental pairs (BROOM → FLOOR; a broom is used *to sweep* a floor). Indeed, such instrumental relations were found to have significantly lower integrative ratings than other thematic relations (Jones, 2010). Though we found no differences in priming magnitude between relationally integrative (e.g., TOMATO SOUP) and thematic (e.g., BOWL SOUP) pairs, target word recognition was differentially related to familiarity ratings and local co-occurrence measures (Google hits) for the integrative pairs and to more global co-occurrence measures (e.g., LSA) for the thematic pairs (Jones et al., 2011).

Like the more traditionally studied *taxonomic* and *similar* prime-target pairs, these thematic prime-target pairs may or may not also share a moderate to strong association. Moreover, some of these thematic relations produce equally robust priming effects in the presence or absence of an association. In a study using both ERP and behavioral measures, Chwilla and Kolk (2005) found a reliable 25-ms priming effect for unassociated thematic relations. They used a variant of a double LDT in which two primes (MOVE and PIANO) were presented immediately prior to the target (BACKACHE) in order to better create a story-like script in which none of the three words shared an association. These primes remained on the screen with the target, and participants judged whether all three items were real words. Moreover, the N400 priming effect differed from the scalp distribution found in the N400 for associative and semantic relations. In a subsequent experiment that increased thematic processing, participants judged whether the three words formed a plausible scenario. In comparison to the results in the LDT, the plausibility judgment task yielded larger priming effects and an N400 distribution that was more characteristic of that seen for semantic relations in its scalp distribution. Chwilla and Kolk concluded that a global integration process (see also Hess et al., 1995) accounted for their obtained thematic priming.

Two factors that affect thematic priming are the frequency and recency of the given relation. For instance, CHOCOLATE is integrated most frequently via a compositional relation (e.g., CHOCOLATE COIN), and is integrated only infrequently via a selling relation (e.g., CHOCOLATE SHOP). Words are integrated faster if they instantiate a frequent relation than an infrequent relation (Gagné and Shoben, 1997; Maguire et al., 2010; Storms and Wisniewski, 2005). Relations are also inferred on the basis of their recency, as evident from *relation priming*, whereby a target phrase is understood more quickly when preceded by a prime phrase that instantiates the same relation (e.g., WOOD CHAIR → CHOCOLATE COIN) than a prime with a different relation (e.g., WOOD SHOP → CHOCOLATE COIN; Estes, 2003; Estes and Jones, 2006; Raffray et al., 2007). Thus, the frequency and recency of thematic relations both affect lexical priming.

Hare et al. (2009) found priming for both associated and unassociated event (script) relations using semantic rather than lexical decision tasks. They found robust priming for object targets following event primes (PICNIC → BLANKET), location primes (GARAGE → CAR), and instrument primes (OVEN → COOKIES), and for people/animal targets following event primes (REUNION → FRIENDS) and location primes (BARN → COW), but not for instrument-people primes (WRENCH → PLUMBER). Computational analyses with BEAGLE predicted the priming obtained for all but the instrumental-people pairs (i.e., higher cosines for the event than the unrelated pairs). As the authors noted, the instrument-people primes were not sufficiently constraining for the people targets (anyone can use a wrench). In a final experiment, however, priming was obtained for these items in the reverse people-instrument direction (PLUMBER → WRENCH). For each item type, priming effects for only the subset of weakly or unassociated items were equivalent to or higher than the overall priming effect. Hence, the obtained priming was not attributable to association strength. Rather this event-based knowledge forms an accessible part of a concept's meaning, which facilitates overall language comprehension upon encountering the word in context.

Together the Chwilla and Kolk (2005) and Hare et al. (2009) studies demonstrate that schematic knowledge is activated in a semantic decision task or in a highly strategic double LDT. However, in a continuous LDT (Moss et al., 1995), reliable priming did not obtain for either associated (GALLERY → ART) or unassociated (PARTY → MUSIC) script relations. This failure to find script priming in a continuous LDT suggests limits in the lexical activation of targets by schematically related primes. We (Estes and Jones, 2009) found lexical activation of relationally integrative unassociated prime-target pairs (OCEAN → FISH; *locative* relation) in a double LDT, and in a standard LDT with SOAs ranging from 100 to 2500 ms.

These studies (Chwilla and Kolk, 2005; Estes and Jones, 2009; Hare et al., 2009; Moss et al., 1995) illustrate that priming occurs as a result of the integration of two nouns based on a unifying relation (e.g., *locative*) or common theme. This thematic priming is similar to that previously found for transparent compounds (e.g., LIP → STICK) and phrasal associates (e.g., WIND → MILL; Hodgson, 1991; Koivisto and Revonsuo, 2001; Seidenberg et al., and1984). Thus, co-occurrence models (e.g., BEAGLE, Jones and Mewhort, 2007; LSA, Landauer et al., 1998) may explain thematic priming among items that also share a strong association (NEST → BIRD). Indeed, word recognition was faster for targets in integrative pairs that also shared a strong association from prime to target (e.g., FLANNEL → SHIRT) than for integrative pairs that were unassociated (e.g., SILK → SHIRT; Jones, 2011). This associative boost in integrative priming occurred at a 500-ms SOA but not at a 200-ms SOA. Moreover, target response times were related to forward association strength as well as to familiarity. Thus, given sufficient time (>300 ms), relational integration may be facilitated or boosted by the formation of an expectancy set consisting of anticipated targets that are strongly associated with the prime (e.g., SHIRT, PAJAMAS, and NIGHTGOWN for the prime FLANNEL). Alternatively, a prime-target compound-cue may be formed and retrieved from LTM thereby bypassing the need for relation inference and role assignment – a process that is especially likely for highly familiar pairs (e.g., BRICK HOUSE, PUMPKIN PIE; Jones, 2011).

However, thematic priming may also occur with little or no lexical co-occurrence or association (Estes and Jones, 2009; Estes et al., 2011b; Jones, 2011). For instance, "monkey" is unassociated with and rarely co-occurs with "foot", but because "monkey foot" can be easily integrated, "monkey" facilitates recognition of "foot". This integrative priming occurs with SOAs as short as 100 ms

(Estes and Jones, 2009; Jones et al., 2011) and with target presentation as brief as 20 ms (Estes et al., 2011b). Such integrative priming without lexical association, semantic similarity, or compound familiarity cannot be explained by standard mechanisms like spreading activation, expectancy generation or compound retrieval, which are based on association and familiarity. At the same time, the fact that such integrative priming occurs at short SOAs and with very brief target durations also excludes retrospective mechanisms like semantic matching. More work is needed to test this hypothesis, but it appears that thematic priming is role-based (Estes and Jones, 2009; Hare et al., 2009). For example, hearing or reading "jungle" activates the "habitat" role, thereby facilitating recognition of subsequent words that denote typical "inhabitants" such as "bird", even though "jungle" and "bird" might not co-occur frequently in language. Thus, priming of more familiar thematic pairs (e.g., "flannel shirt") may be due to expectancy generation or compound retrieval (Jones, 2011) but priming of more novel thematic pairs (e.g., "monkey foot") appears to be due to thematic role activation.

Mediated priming

Mediated priming (a.k.a., two-step or indirect priming) is a facilitated response to a target (e.g., MOUSE) following a prime (e.g., DOG) that is indirectly related to the target via a connecting mediator (e.g., cat). Some researchers (McKoon and Ratcliff, 1992; Ratcliff and McKoon, 1994) argued against the existence of mediated priming and stated that it was due to co-occurrence (albeit a weak one) between the indirectly related prime and target (but see McNamara, 1994). Indeed, some prior findings of mediated priming may have been attributable to co-occurrence. Livesay and Burgess (2003) assessed the co-occurrence of the mediated and control items originally used by Balota and Lorch (1986). They found lower co-occurrence for the unrelated primes and targets than for the mediated prime-target pairs. More recently, Jones and Mewhort (2007) also found higher co-occurrence (BEAGLE cosines) for the mediated than the unrelated Balota and Lorch items. Chwilla and Kolk (2002) used LSA to assess co-occurrence. Unfortunately, however, their mediated items were also much higher in co-occurrence than were their unrelated control items.

However, most studies have argued that spreading activation from prime to mediator and then from mediator to target underlies mediated priming (e.g., Bennet and McEvoy, 1999; McNamara, 1992a, b, 1994; McNamara and Altarriba, 1988; Shelton and Martin, 1992). Indeed, the occurrence of mediated priming has been regarded as strong support for spreading activation models (Hutchison, 2003). However, the findings of mediated priming have been largely inconsistent, with some studies showing robust priming effects (e.g., Bennet and McEvoy, 1999; McNamara and Altarriba, 1988; Shelton and Martin, 1992), and other studies failing to find mediated priming (e.g., Balota and Lorch, 1986; de Groot, 1983). One often cited reason for the failure to find mediated priming is a list effect produced by the inclusion of both directly and indirectly related (mediated) items within the same experimental list. This list effect is especially likely to occur in the more strategic lexical decision tasks, in which participants are aware of the prime-target pairings (Chwilla and Kolk, 2002; McNamara and Altarriba, 1988; Sass et al., 2009). The presence of directly related associates (DAY → NIGHT) may elicit a relatedness checking strategy in tasks allowing detection of prime-target pairs (McNamara and Altarriba, 1988). In a double LDT paradigm, mediated priming effects are heavily affected by the inclusion of more strongly related items (e.g., directly associated items). Chwilla and Kolk (2002) found priming in a mediated only list and no effect in the "mixed" (mediated plus direct) list.

This list effect (Chwilla and Kolk, 2002; McNamara and Altarriba, 1988) suggests that mediated priming may utilize strategic processes (e.g., noticing the stronger associative relation and using that relation to guide lexical decisions). Moreover, recent neuroscience studies (Chwilla et al., 2000; Sass et al., 2009) have suggested that post-lexical or semantic matching processes may partially explain mediated priming. For example, in an fMRI study, Sass et al. (2009) found greater activation in areas of the right hemisphere reflecting greater attentional demands indicative of a retrospective post-access search strategy.

These studies indicate that associative strength may not be a requirement for mediated priming. To test this hypothesis, Jones (2010) assessed mediated priming across a double LDT, a standard LDT, and a continuous LDT for items having no more than a weak association. Moreover, the primes shared an instrumental relation with their mediators (SPOON → SOUP) whereas the mediators and targets were connected by an integrative relation (SOUP → CAN; *contains*). Finally, co-occurrence was equated between the mediated and unrelated prime-target pairs. Mediated priming was strongest in the double LDT and was also reliable in the standard LDT. However, mediated priming did not obtain in the continuous LDT, thereby indicating a retrospective semantic matching and not a prospective process for pure mediated priming.

Though lexical association is not required for mediated priming, it does influence whether mediated priming can occur prospectively by spreading activation or expectancy at longer SOAs. Several studies found reliable mediated priming in more automatic tasks (e.g., Bennett and McEvoy, 1999; McNamara and Altarriba, 1988; both within a continuous LDT), whereas other studies have not (e.g., de Groot, 1983, Experiment 7, within a masked priming experiment; and Balota and Lorch, 1986, within a word naming task). An analysis of the items used in these experiments revealed a strong forward association (> 0.25) between mediator and target within the studies that exhibited mediated priming in a more automatic task, but only a weak mediator-target association in those studies that exhibited no mediated priming. Indeed, de Groot (1983) speculated that failure to obtain mediated priming may be due to a decay in spreading activation, with an insufficient amount of the activation that is needed for further spread from the mediator to the target. Jones (in press) tested this hypothesis by systematically varying the mediator-target association strength (weak versus strong) while holding the prime-target association strength constant. Consistent with previous findings, mediated priming was reliable in tasks favoring a prospective process

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(i.e., continuous LDT and a standard LDT with a long 1800-ms SOA) for the items having a strong mediator-target association (e.g., CRATER → moon → SUN) but not for those with only a weak mediator-target association (e.g., RAIN → storm → SUN). Further item analyses demonstrated a reliable relationship between the forward mediator-target association strengths and the mediated target RTs within these tasks, which was suggestive of a spreading activation and expectancy hybrid process similar to the one proposed by Neely et al. (1989). That is, for the strongly associated mediator-target items, activation may spread from prime to mediator (e.g., CRATER → MOON), and then the target would be pre-activated by inclusion in an expectancy set of words related to the mediator (e.g., for MOON, the set would likely include the moderate and strong associates SUN, STAR, FULL, and NIGHT).

The above studies illuminate several methodological and theoretical implications. First, the presence of directly related prime target pairs within the same experimental list may overshadow the mediated pairs (McNamara and Altarriba, 1988). Co-occurrence needs to be equated between the experimental and unrelated control conditions and evaluated as a potential underlying factor. Mediated priming studies should use a variety of relations, association strengths, and tasks to determine which lexical priming model(s) may explain the obtained mediated priming. For example, double LDTs evoke more strategic processing than standard LDTs, and therefore permit more retrospective processing, whereas the more automatic continuous LDT favors prospective processing.

Individual differences in lexical priming

Lexical priming in healthy and cognitively impaired older adults

For healthy older adults, most studies have found few if any changes in the magnitude of lexical priming, despite longer overall response times (e.g., Bennett and McEvoy, 1999; Burke et al., 1987; Laver, 2009; for review see Laver and Burke, 1993). However, when RTs were standardized to control for this overall difference in response speed, younger adults exhibited greater lexical priming than did older adults (Hutchison et al., 2008). Hence, future research in lexical priming needs to compare the standardized RTs between younger and older adults to account for the overall longer RTs and the greater individual variation in older adults.

Lexical priming can serve as an effective mnemonic device among healthy older adults. Badham et al., (in press) examined integrative priming among normal older adults (mean age = 73 years). They first demonstrated that older adults, like young adults (Estes and Jones, 2009), exhibit integrative priming. They then tested older adults' and young adults' memory for integrative and semantically similar word pairs. For instance, participants studied either "monkey foot" (integrative), "paw foot" (semantic), or "campus foot" (unrelated baseline), and they were later given the first word of each pair (i.e., "monkey", "paw", or "campus") and were asked to recall the second word of the given pair.

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Among young adults, both integrative and semantic relations facilitated recall relative to unrelated pairs (see also Jones et al., 2008). Importantly, the same pattern occurred among healthy older adults (Badham et al., in press). Thus, lexical priming continues to play an important role in cognition throughout adulthood (e.g., Old and Naveh-Benjamin, 2008).

Expectancy processing is particularly vulnerable to cognitive impairment. Both those with mild cognitive impairment and healthy older adults exhibited an expectancy bias in a high (0.80) RP condition, in which 80% of the stimuli were exemplar-category pairs (APPLE-FRUIT; Davie et al., 2004). However, those with mild cognitive impairment exhibited even less priming for the unexpected category coordinate pairs (APPLE-PEAR).

Cognitive impairments may also lead to greater priming effects. For example, those in the early stages of Alzheimer's disease exhibit larger priming effects than control participants between category coordinates (e.g., increased activation of LION following TIGER). This *hyperpriming* is due to the loss during the earliest stages of semantic deterioration of a concept's attributes (e.g., stripes, mane) but not yet the categorical membership of the concept (i.e., both lions and tigers are still recognized as wild animals). Hence, these participants exhibit activation of the more general categorical representation wild animal for the prime concept TIGER, which in turn facilitates activation of the target concept, LION, which is also recognized as a wild animal. This repetition priming among Alzheimer's patients (wild animal → wild animal) is larger than the semantic priming exhibited between two category coordinates (TIGER → LION).

Lexical priming and conceptual organization in childhood

One avenue of developmental research compares the emergence of various conceptual organizations across the lifespan. Children demonstrate a conceptual shift from organization via thematic, functional, or instrumental relations to categorical relationships (Murphy et al., 2003; Perraudin and Mounoud, 2009; for review see Estes et al., 2011a). In a naming task, Perraudin and Mounoud found that 5-year-old children exhibited a robust priming effect for instrumental word pairs (e.g., KNIFE → BREAD), but only a marginal effect for the taxonomic word pairs (e.g., CAKE → BREAD). In contrast, the 7-year-old and 9-year-old children and the young adults exhibited both instrumental and categorical priming. The finding of more robust instrumental priming for the 5-year-olds than for the other age groups further reflected this conceptual shift. Importantly, the association strengths were kept low in both conditions, thereby reflecting the influence of the relations themselves rather than association strength. Perraudin and Mounoud's results are consistent with Nation and Snowling's (1999) findings of reliable functional priming for good and poor 10-year-old readers and adults in the absence of a strong association, but categorical priming for poor 10-year-old readers only in the presence of a strong association.

Another avenue of research concerns the emergence of facilitation versus inhibition processes in lexical priming. Hence, the faster RTs for real word targets following related in comparison to unrelated primes may be due to either facilitation (related primes increasing target activation) or inhibition (unrelated primes decreasing target activation). Though the overall effect sizes of semantic priming do not differ between children and adults, inhibition effects are larger in children and facilitation effects are smaller, hence suggesting a greater ease in spreading activation as the individual's semantic network develops (Nakamura et al., 2006). Indeed, inhibitory processing emerges earlier in childhood than other components of executive functioning (*EF*, for review see Best et al., 2009). Future research could incorporate a variety of tasks ranging from the more automatic (naming, continuous LDT) to the more strategic (double LDT, standard LDT with long SOAs and a high RP) to investigate the use of strategic versus automatic processing in lexical priming.

Executive functioning, attention, and other cognitive abilities

Even among young adults of the same age, recent research (e.g., Estes and Jones, 2009; Stolz et al., and2005) has found individual variation in the prevalence and extent of lexical priming. Assuming that measures have been taken (e.g., standardization of RTs) to account for the greater individual variation occurring within the LDT than in naming tasks and within certain populations (e.g., older adults and children; Hutchison et al., 2008), then differences in EF may explain many of the obtained differences in lexical priming.

Executive functioning is typically conceptualized as three distinct yet correlated components: working memory, inhibition, and shifting (Miyake et al., 2000). The combination of these three EF components has been characterized in the lexical priming literature as "attentional control" (Hutchison, 2007) or "executive control" (Kiefer et al., 2005). Hutchison (2007) found greater RP effects indicative of greater strategic (expectancy) processing for individuals scoring higher on a battery of EF measures, including measures of working memory and inhibition. In contrast, mediated priming occurred for individuals lower in working memory capacity but not for those high in working memory capacity (Kiefer et al., 2005). This finding is consistent with the greater mediated priming among those with thought-disorder schizophrenia (e.g., Spitzer et al., 1993). Hutchison (2007) and Kiefer et al. (2005) illustrate an underlying involvement of the prefrontal cortex in automatic tasks (indirect associative mediated priming) and in strategic tasks (expectancy processes in a RP manipulation). Notably, individuals with better EF exhibit greater priming in strategic tasks requiring effortful control, whereas those lower in EF exhibit greater priming in more automatic tasks. Indeed, individuals with higher working memory capacities are able to maintain focused attention on a target in the presence of distratctors over a longer period of time than those with lower working memory capacities (Poole and Kane, 2009).

Further research is needed to investigate the underlying role of EF in other forms of priming such as thematic/integrative priming. Prefrontal cortex activation is greater for maintaining integrated rather than non-integrated verbal and spatial information (Prabhakaran et al., 2000), thereby demonstrating the role of increased working memory in integration. Moreover, integrative processing requires focused attention in order for binding elements of a proposition (e.g., Doumas et a., 2008) and in integrative pairs (e.g., PAPER CUP) between relations (e.g., *compositional*) and roles (e.g., *material* and *object*; Estes and Jones, 2008, 2009). Thus, individual differences in executive control are likely to relate to the individual variation found in integrative priming (Estes and Jones, 2009).

In addition to examining individual differences between those with higher versus lower working memory capacities, the ability to maintain attentional control can also be experimentally manipulated in divided and selective attention tasks. Priming effects for semantically related pairs (CLOCK → TIME) in comparison to unrelated pairs (CIGAR → TIME) in a standard LDT were greater in a full attention condition than in a divided attention condition, in which participants had to determine whether a tone presented with the prime matched the tone presented with the fixation cross (Otsuka and Kawaguchi, 2007). The difficulty of the auditory attention task was also manipulated such that priming still occurred but to a lesser extent in the low divided attention condition in which two dissimilar tones were presented but disappeared in the high divided attention condition in which two very similar tones were presented.

Attention can also be increased by directing focus onto a particular stimulus dimension such as the semantic category of the prime. Following a semantically related prime word, Spruyt and colleagues (2009) cued participants to either (i) name the presented target or (ii) verbally evaluate the target by stating “animal” or “object”. The targets exhibited priming only when evaluation responses were made to the remaining 75% of the trials; no priming occurred when only 25% of the trials were evaluated. Hence, in the 75% evaluation condition, directing attention to a relevant stimulus dimension (in this case the broad semantic category) increased attention to the categories of the prime-target pairs on the remaining trials. This result is similar to the RP effect (e.g., Hutchison, 2007), in that the focusing of attention onto a common stimulus dimension occurs without explicit instruction.

Other potential moderators of lexical priming include verbal ability (e.g., Nation and Snowling, 1999; Ron-Kaplan and Henik, 2007), creativity (Whitman et al., 2010), and convergent thinking. For example, mediated priming requires the ability to detect a relation between two seemingly unrelated concepts (e.g., WIND and STRING are related via the mediator kite). Likewise, the Remote Associates Task (RAT; Mednick, 1962) also requires participants to think of a word that can conceivably connect three other seemingly unrelated words (e.g., “card” relates to credit, report, and playing). Hence, individuals who score higher on the RAT are likely to exhibit greater mediated priming. Another often used measure of thinking and creativity, analogical reasoning ability, may underlie the individual variation in integrative priming. Like analogical reasoning, relational integration also requires the inference of a relation between two concepts (Estes and Jones, 2008; Leech et al., 2008). Thus, the general ability to detect a specific and plausible relation should predict larger integrative priming effects.

Future directions and conclusions

Research on lexical priming seems to gradually be shifting from broad categories of prime types (associative vs pure semantic vs integrative) towards more specific relations, such as antonyms versus synonyms (e.g., Perea and Rosa, 2002; Roehm et al., 2007) and event-related knowledge (e.g., location-thing vs location-object; Hare et al., 2009). Priming differences may also exist among various relation types within integrative priming (e.g., locative, ISLAND → HOUSE vs compositional relations, LOG → HOUSE). Prime-target relations likely vary in accessibility (Chwilla and Kolk, 2005). Furthermore, the type of relation may interact with various individual differences. For example, some individuals may find a locative relation to be more accessible whereas others may find a compositional relation to be more accessible. More research is needed to further illuminate differences in the accessibility of various relations across individuals and lexical priming paradigms.

In this chapter we have described several different types of lexical priming, along with several different mechanisms that have been proposed to explain lexical priming. Our general conclusion from this review is that no single model is able to fully account for the varieties of lexical priming. Rather, because lexical priming has been observed across such a diverse range of methods, experimental conditions, and individual factors, it has become clear that lexical priming arises from multiple sources. In our opinion, this conclusion follows naturally from the extremely important role that lexical priming plays in language processing: Lexical priming occurs very frequently during normal discourse and reading, thereby facilitating rapid and effective communication. It therefore should come as little surprise that humans have adapted multiple mechanisms for capitalizing on context to facilitate word recognition under a great variety of conditions.

- Lexical priming occurs when the response to a target word varies systematically as a function of the preceding linguistic context.
- Lexical priming can be measured via a number of experimental paradigms, including lexical decisions (i.e., word/nonword judgments), word naming (i.e., reading aloud), perceptual identification of briefly presented words, semantic decisions (e.g., animacy judgments), eye tracking (i.e., optical fixations), and neuroimaging (e.g., the N400).
- Lexical priming may result from several mechanisms, including spreading activation (i.e., the prime word automatically activates associated and similar target words), expectancy (i.e., the participant generates a set of expected targets that typically follow the prime word), semantic matching (i.e., the participant checks whether the target is related to the prime), episodic retrieval (i.e., the participant

retrieves stored episodes of the prime and target), and thematic integration (i.e., the participant integrates the prime and target meanings).

- Lexical priming occurs among several types of primes and targets, including those that are linguistically associated (i.e., they frequently co-occur; e.g., DAY → NIGHT), semantically similar (i.e., they share many features; e.g., CAT → DOG), or easily integrated (i.e., they form a sensible phrase; e.g., HORSE → DOCTOR). Lexical priming can also occur among primes and targets that are related by a third, mediating concept (e.g., LION → tiger → STRIPES).
- Lexical priming emerges early in childhood, remains robust across adulthood, and is accentuated by some cognitive impairments (e.g., Alzheimer's Disease, thought-disordered schizophrenia). Lexical priming appears to be related to several components of executive functioning, such as working memory and attentional control.
- In sum, lexical priming capitalizes on context via multiple mechanisms to facilitate rapid and effective word recognition.

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