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Primed to Cue

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Abstract

The behavioral effects of lexical priming are well studied in the cognitive sciences. Clinical use of the term and widespread implementation of priming based behavioral interventions has remained limited. This is despite the fact that response-contingent cueing, a behavioral intervention technique used during many cognitive-linguistic interventions, is *grounded* in theories of priming research. The aim of this manuscript is to connect behavioral performance changes observed following priming with those noted following cueing, providing a theoretical rationale for the therapeutic use of both priming and cueing in language and cognitive interventions. In this review, we establish a conceptual basis for how both primes and cues serve to pre-engage the neural system by triggering the retrieval of linked conceptual knowledge, resulting in faster and more accurate responses. Differences between the two (primes and cues) have been linked to timing and conscious intentional engagement, though these distinctions are often task dependent. Additionally, this paper will provide evidence of the clinical utility of priming. Studies of priming in adults with acquired brain injuries are discussed and clinical interventions based on theories of priming are examined. Furthermore, the present work will briefly detail the inhibitory effects of priming to aid clinicians and researchers in deciding how to pair primes and cues with intended retrieval targets. In summation, the present work is intended to bridge two related fields providing both theoretical and clinical insight with respect to the use of primes and cues.

Introduction

Cognitive-linguistic interventions are intended to both re-engage and facilitate recovery of a damaged neural system. Interventions based on principles of experience-dependent plasticity use systematic amounts of focused stimulation paired with repetition and practice in differing contexts to aid individuals who have been hindered by neurological injury or disease (Kleim & Jones, 2008; Thompson, 2000). A primary component of many language and cognitive interventions is response-contingent cueing in which a clinician provides a tactile, visual, or verbal stimulus to enable a client to produce a target reply or behavior. Clinicians use cues as a means to activate targeted conceptual and phonological information, subsequently triggering the retrieval process. Cues are faded out as production of target behaviors and responses becomes routine. Investigations of the effectiveness of cueing have revealed that cues are beneficial, aiding linguistic processes such as word retrieval (Cameron, Wambaugh, Wright, & Nessler, 2006; Macoir, Leroy, Routhier, Auclair-Ouellet, Houde, & Laforce, 2015; Wright, Marshall, Wilson, & Page, 2008). While cueing is a generally understood and accepted practice across a variety of disciplines, priming—a theoretically similar yet distinct concept—is not as well known or understood.

Priming is a complex term that refers to both a technique of facilitation and, relatedly, a form of implicit memory. As a facilitatory technique, priming can occur consciously or subconsciously when one stimulus is presented to engage or initiate cognitive processes prior to the presentation of a second stimulus, from which some type of response is elicited (e.g., lexical retrieval and subsequent naming of the object). The stimulus shown prior to the target is referred to as the prime (See Figure 1). Presentation of the prime is done to bring information necessary for completion of a target response to a point of heightened cognitive awareness or activation (Meyer & Schvaneveldt, 1971; Tulving & Schacter, 1990; Schacter, 1992). This heightened cognitive awareness/activation results in faster processing and/or accurate selection of the desired response when the target stimulus is presented (Meyer & Schvaneveldt, 1971; Tulving & Schacter, 1990; Schacter, 1992). A primed lexical item or object, for example, is an entity that is readily available and active because it was previously retrieved or conceptually situated near a target that was recently accessed (Holocomb, 1993; Neely, 1977; Discussed in detail in the section: Theoretical Foundations for Priming). Similarly, in terms of implicit memory, priming refers to information that was recently acquired that alters behavioral performance without conscious retrieval (Schacter, 1992; Schacter, Chiu, & Oschsner; 1993).

{Insert Figure 1}

The goal of the present work is to examine priming in conjunction with, and in comparison to, cueing, with the intent of providing clinicians with a theoretical and functional understanding of these two related, yet distinct concepts. Clinical cueing mirrors experimental priming in many ways with the primary distinctions related to timing of presentation, type of response requested, and the facilitation of conscious cognitive engagement. In this review, we will examine the use of cues and primes and their influence on adults who have an acquired brain injury. We will review research of neurotypical adults as well as adults with acquired brain injury to understand how priming informs our understanding of retrieval processes. Lexical priming and word retrieval will be our primary areas of focus with other uses of priming reviewed succinctly as needed to support the current discussion. Though the focus of this paper is targeted toward adults with acquired neurogenic communication disorders, the techniques discussed are likely to be influential for multiple demographics**.** Our intent is to provide a theoretical basis for how cues and primes result in an enhanced behavioral response, while also discussing potential implications of using priming as a component in cognitive-linguistic interventions. Priming research can provide a template for structuring cues, providing clinicians and researchers with increased insight regarding how to tailor cues to engage strategic processes supporting cognitive recovery post neurological injury.

This review is segmented into four main sections. The first provides a basic framework of priming including a brief discussion of two dominant theories of the underlying mechanisms governing how primes trigger conceptual activation influencing word retrieval. The second details cueing providing a theoretical motivation for the use of cueing in cognitive and linguistic interventions and linking cues with theories of priming. This section is intended to provide insight regarding cueing, while comparing and contrasting the use of cues during intervention to primes used in experimental research. The third section presents several language interventions that are directly linked to priming. The goal of this section is to provide insight into how priming has been incorporated into treatment protocols as a means to support word retrieval in neurologically impaired populations. The fourth section briefly details factors that can trigger inhibitory processes impeding response retrieval. The paper will conclude with a brief summary of findings before looking at future directions of research.

Priming

Priming is a form of implicit memory that is linked to semantic memory (Tulving & Schacter, 1990). Unlike explicit memory, which requires conscious retrieval of targeted information (Schacter, 1990), implicit memory is a change in performance resulting from newly acquired competence and can occur without conscious recollection of the enhancing experience (Schacter, 1992; Schacter, Chiu, & Oschsner; 1993). Research examining explicit and implicit processes require multiple assessments because of the distinct nature of each of these constructs.

Implicit Responses.

Tasks used to assess implicit memory examine changes in behavioral performance without necessitating conscious engagement of encoded information; whereas assessments of explicit (declarative) memory involve conscious recollection evidenced by an intentional (explicit) response (Roediger, 1990). Implicit memory is commonly examined using language processing tasks designed to elicit a priming effect (See Figure 1). Lexical decision, word-fragment, and word-stem completion tasks are among the most commonly used tools to assess a priming effect with faster and more accurate performances on these tasks taken as an indication of a strong connection between the prime and the word target (McNamara, 2005; Meyer & Schvanedevelt, 1971). During a lexical decision task, participants are asked to identify if test items (e.g., a string of letters or sounds) are words or non-words. The tests assess areas such as conceptual knowledge and lexical access. Response latencies are the primary dependent variable collected from these tasks and refer to the amount of time it takes to make a decision regarding the test stimuli. It is theorized that the amount of time taken to respond is directly related to the amount of time it takes to activate the targeted information to a threshold, indicating a decision has been made (Cree et al., 1999). As previously noted, response latencies are shorter and responses are more accurate when the presented prime and word target are associated or semantically related (Fischler, 1977; Meyer & Schvanedevelt, 1971).

As previously noted, word-stem and word fragment completion tasks are also widely used assessments of priming effectiveness. The general idea of each task is the same, though presentation is slightly different. Participants are shown a prime and then asked to complete a word when several of the letters have been provided to them. Prior exposure to a word is expected to result in an enhanced performance in completing that word or in producing a related word. This occurs spontaneously, without explicit intention to recall information that was presented earlier (McNamara, 2005; Roediger, 1990). Priming success is measured in the time and accuracy with which participants complete each task. Both word-stem completion and word-fragment completion have been successful in identifying priming effects with direct comparison of the two indicating that both tasks similarly assess implicit memory processes (Roediger, Stadler, Weldon, & Riegler, 1992). A breakdown of implicit and explicit tasks is presented in Figure 2.

{Insert Figure 2}

Implicit effects are commonly assessed using a masked priming task to reduce the potential confounds that may occur due to participant awareness of the presence of a prime (McNamara, 2005). Masked priming is an experimental manipulation in which the prime is quickly presented prior to the presentation of the target, so that the prime does not register consciously (Forster & Davis, 1984). Though priming can occur visually or aurally, the former is more commonly deployed with tasks utilizing masking. In a visual masked priming task, the mask (frequently a set of hash marks) is presented, shielding the prime, so that study participants are unaware that a prime was presented. An example is detailed in Figure 3. Research has shown that awareness of a prime is not necessary for the prime to significantly influence behavioral performance (Draine & Greenwald, 1998; Naccahe & Daheane; 2001; Van den Bussche, Van den Noortgate, & Reynvoet, 2009). The lack of dependence on conscious intentional awareness during retrieval is again a distinguishing feature of implicit memory. This is perhaps best demonstrated by research findings from individuals with amnesia for whom the effect of priming remains intact though explicit recall is impaired (e.g., word recognition for a previously presented list) (Cermak, Blackford, O'Connor, & Belch, 1988; Gabrieli et al., 1994; Graf, Squire, & Mandler, 1984). Priming can be linked with volitional engagement, particularly if individuals are intentionally trying to link paired stimuli to produce a response. This will be examined later in the discussion of behavioral interventions that are based in theories of priming. For the moment, we will direct our attention towards various means of assessing behavioral responses.

{Insert Figure 3}

Semantic and Repetition Priming.

Primed responses can be elicited in several ways. We will focus on semantic and repetition priming because they most resemble methods used by clinicians when engaged in treatment to prompt a response from an individual with an acquired brain injury.

Semantic priming refers to the facilitation of a faster response to a target due to prior exposure to a stimulus that is related in meaning (Meyer & Schvaneveldt, 1971; Neely, 1977). Repetition priming consists of repeated exposure to a given target prior to acting on that target (Forster & Davis, 1984; Scarborough, Cortese, & Scarborough, 1977). Both types of priming result in faster more accurate responses when a participant is asked to identify or retrieve a target (Scarborough et al. 1977; See Figure 1). The more rapid response observed when an individual is presented with related concepts, such as during semantic priming, is considered an indication that there is a shared underlying conceptual representation supporting those concepts (Collins & Loftus, 1975; McNamara & Holbrook, 2003).

Items with similar meanings (e.g., fox, wolf, and coyote) are likely to have similar patterns of neural activation indicative of shared conceptual representation linked with their level of semantic similarity (Badre & Wagner 2002; McNamara, 2005; this is further detailed in our section on models of priming). It is important to note the level of conceptual activation (i.e., the extent of the heightened response) facilitated during semantic priming is not solely linked to meaning. The strength of the association between two items can influence the level of response

(Lucas, 2000). Closely linked concepts (e.g., dog and bone) result in a stronger facilitation of response, even if they do not share meaning. This indicates that association plays a major role in the underlying representation of conceptual knowledge (Lucas, 2000).

Repetition priming is theorized to engage the neural system in a manner similar to semantic priming. Presenting a stimulus several times reduces the cognitive resources needed to attend to it resulting in a faster response (Dobbins, Schinyer, Verfaeillie, & Schacter, 2004). Similar to semantic priming, repeated activation of the same concept likely allows that concept to stay at a heightened state of attunement. At the neural level, repeated exposure to a stimulus can result in the suppression of cells that are not necessary to analyze the target reducing cortical activation (Gotts, Chow, & Martin, 2012; Wiggs & Martin, 1998). Similar neural patterns have been reported following semantic priming (Rissman, Eliassen, & Blumstein, 2003). Decreased cortical activation has been viewed by many as support for cortical tuning in which neurons responsive to initial processing display a decreased response because they are no longer needed (Henson, 2003; Race, Shanker, & Wagner, 2009).

In summation, both semantic and repetition priming result in a better allocation of resources, aiding semantic processing. There are multiple theories of semantic processing and conceptual storage that provide insight into the underlying mechanism supporting priming. The next section will briefly introduce two: spreading activation theory and distributed processing.

Theoretical Foundations for Priming

Spreading Activation Theory.

Spreading activation models are commonly used as a means of representing semantic processing. They are intended to detail how underlying representations are activated as a result of exposure to content related to a given concept. Activation of this underlying information triggers a neural cascade that spreads to related concepts (See Figure 4). The informational cascade is theorized as the reason why priming results in the faster identification of semantically related concepts. Multiple spreading activation models have been proposed with each based on the core idea that retrieval requires the activation of an internal representation that is connected to a related concept (McNamara, 2005; Plaut, 1995). We will discuss two of the more prominent models: a model by Collins and Loftus (1975), which helped establish spreading activation as a template for cognitive processing, and a model by Dell and colleagues (1997), which utilized spreading activation to account for production deficits in persons with aphasia.

Collins and Loftus (1975) developed one of the most prominent spreading activation models. In their model, concepts are represented by a network of nodes. Memory retrieval requires traveling across links that connect each of the various concepts. Concepts that are more semantically related have shorter links, with smaller subordinate concepts (e.g., rain, snow) connected to a larger overarching concept, the superordinate representation (e.g., weather). One of the driving factors of the model is that when a concept is activated, related concepts that are closely linked are also activated making them easier to retrieve. Activation of related concepts continues for a period diminishing in strength over time and distance. This model helped pave the way for later models that examined lexical retrieval in impaired populations.

{Insert Figure 4}

Dell and colleagues (1997) developed a model of lexical access. Using spreading activation theory, the model attempts to explain the error patterns produced by individuals with and without aphasia on a picture naming experiment. The model was parameterized utilizing data collected from 23 persons with aphasia and 60 neurotypical controls on the Philadelphia Naming

Test (Roach, Schwartz, Martin, & Grewal, 1996). The developed model is bidirectional and consists of three layers: semantic features, words, and phonemes. Five categories of naming errors were included in the model and were represented at the word level. The categories were as follows: semantic (e.g., 'van' for 'boat'), form (e.g., 'goat' or ‘bone’ for 'boat'), unrelated (e.g., ‘leg’ for 'boat''), a combination of semantic and form (e.g., 'float ' for 'boat), or a non-word (e.g., 'blut' for 'boat'). The bidirectional nature of the model links semantic features and phonemes enabling multiple routes to trigger activation of concepts.

At its core, Dell and colleagues’ (1997) model of lexical access details how the conceptual representation of a word (referred to as a lemma) can be accessed and transformed into speech. All three layers of the model are active during production and the word that is most highly activated and grammatically appropriate is retrieved. Bidirectional spreading activation enables all three layers to be active simultaneously. Errors in the model occur when spreading activation triggers the wrong semantic or phonological representation. In order to enable the model to produce error patterns anticipated from persons with aphasia, activation levels were manipulated (i.e., reduced or decayed). The model was highly accurate in classifying persons with and without aphasia indicating that lexical access deficits may result from difficulty with the ability to produce and sustain the neural activation necessary to bring a word target from conceptual representation to phonological form.

Distributed Network Model of Semantic Processing.

In general, spreading activation models tend to group related concepts into a single locale, facilitating the spread of activation between linked concepts. Distributed network theories offer an alternative view in which conceptual information about a word (e.g., semantic features) is represented as occurring in a pattern of activation across processing units. In this way, different, but related concepts make use of some of the same neural units (Plaut, 1995). Distributed models are, in principle, agnostic about what types of information can be represented in their units. This means that units could represent phonological, orthographic, or semantic information. An example of a distributed model is depicted in Figure 5.

{Insert Figure 5}

Regardless of which model best fits the underlying mechanisms involved, there is ample evidence that individuals produce responses more efficiently with less effort following priming (Lucas, 2000; Van den Bussche, Van den Noortgate, & Reynvoet, 2009). The improved behavioral performance observed following priming (both repetition and semantic) is akin to what is observed when clients improve following cueing during cognitive-linguistic interventions. This is not surprising given that the principles hypothesized to govern priming (i.e., spreading activation model or distributed model frameworks) provide theoretical support for the use of cues. In the next section, we will review several studies that have utilized priming as tool to examine cognitive-linguistic processing following acquired brain injury.

Priming and Processing Following Acquired Brain Injury

A number of studies have examined priming in special populations to better understand the contribution of different neural processes and regions to cognitive-linguistic function (Hagoort, 1997; Milberg & Blumstein, 1981; Ostrin & Tyler, 1993; Myers & Blumstein, 2005). Individuals with aphasia, particularly Broca's-type aphasia, are commonly recruited for investigations of semantic processing. Preference for Broca's-type aphasia is two-fold. First, the specific characteristics of this aphasia type (such as word retrieval difficulty despite relatively spared comprehension) are highly likely to provide insight regarding conceptual activation and retrieval processes. Second, Broca's aphasia has a higher incidence in comparison to other types of non-fluent aphasia (NIDCD, 2015), making this population generally more accessible. Within studies such as these, the role of the inferior frontal gyrus (IFG) tends to be an area of focus as it is implicated in linguistic processing for speech production (Borovsky, Saygin, Bates, Dronkers, 2007; Hickok & Poeppel, 2007; Nishitani, Schurmann, Amunts, & Hari, 2005). It should be noted, however, that IFG damage is not always the source of production impairment (Kasselimis, Simos, Peppas, Evdokimidis, & Potagas, 2017). In behavioral observations of persons with non-fluent aphasia on lexical decision tasks, successfully primed responses suggest that disruptions to speech production in regions suspected of supporting speech are not necessarily indicative of diminished conceptual representations underlying language (Hagoort, 1997; Milberg & Blumstein 1981; Ostrin & Tyler, 1993).

We will now discuss in detail a few studies exemplifying how priming has contributed to our understanding of cognitive-linguistic processing in individuals with acquired brain damage. These studies were included in this discussion as they are particularly well-suited to provide insight into how priming can be directly connected to cognitive-linguistic performance following an acquired brain injury. Myers and Blumstein (2005) utilized a series of semantic priming experiments to determine if syntactic deficits observed in the verbal output of individuals with Broca's aphasia were present at a lower level of lexical processing. Eight participants with aphasia and thirteen neurotypical control participants were given an auditory lexical decision task where they were asked to judge whether the second word of a verb-object pair was real or not. Real word verb-object pairs were divided across three conditions based on the selectional restrictions of the verb (i.e., semantic restrictions for appropriate/plausible verb-object pairings). For example, the first condition contained pairs that were semantically related and satisfied the verb's selectional restrictions (e.g., 'mail letter'). The second condition met selectional restrictions but without a semantic relationship (e.g., 'find letter'). Finally, the third condition consisted of pairs that were not semantically related and did not meet the verb's selectional restrictions (e.g., 'persuade letter'). The authors found that, in both groups, response times for judgement of the second word (i.e., object) were significantly affected by whether it was congruent with the semantic relationship and selection restrictions of the verb prime. These results indicate that individuals with Broca's aphasia are responsive to semantic priming (participants displayed significantly faster reaction times to semantically related verb-object pairs in comparison to the other two conditions). Additionally, faster response times in the condition where verb-object pairs were not semantically related but plausible indicate that selectional constraint information (syntactic and grammatical restraints of a word) is available at the lexical level. In comparison to the control group, participants with aphasia were slower overall, indicating decreased processing speed even when task demands are low. These results provide further indication that semantic representations may not [all] be altered following injury, though access may be impaired.

Individuals with aphasia have also provided considerable insight with regards to automatic versus strategic processing. The presence of a priming effect coupled with longer latencies in response times (in comparison to peers) has been taken as evidence that automaticity is still present in this population, albeit part of a slowed or hindered cognitive system (Prather, Zurif, Love, Brownell, 1997; Prather, Zurif, Stern, Lowell, 1992). Toro (2000) utilized a shortened stimulus onset asynchrony (SOA- the amount of time between the presentation of the prime and the target) to examine whether priming effects for persons with Broca's aphasia were automatic or strategic (i.e., dependent on conscious engagement). Participants with Broca's aphasia were compared with both younger and age-matched neurotypical controls on a visual pairwise lexical decision task. The study utilized categorically high dominance exemplars (e.g., apple is highly typical categorical response for fruit) and categorically low dominance exemplars (e.g., avocado is an appropriate response, but less common) to identify patterns of facilitation and inhibition effects. Increased response time and decreased accuracy were observed among participants with Broca's aphasia. The results indicate that individuals with Broca's aphasia engage in strategic processing, as is evidenced by the reduction in inhibition, which is not adequately accounted for by automaticity (Toro, 2000). It is important to note that age match controls also exhibited difficulty with inhibition with the low dominance exemplars, indicating that both populations may be using retrieval strategies to support semantic processing.

To compare lexical-semantic activation in individuals with Broca's aphasia to individuals with Wernicke's aphasia, Yee, Blumstein, and Sedivy (2008) utilized eye tracking responses as an indicator of a semantic priming effect. Participants were engaged in a task intended to examine whether the groups displayed preference for a target object when a related word was presented aurally (e.g., would participants fixate on a picture of "bread" when they heard the word "butter"?). Both groups displayed a preference for the semantically related object, indicating access to lexical-semantic information.

Priming has also been pertinent to furthering our understanding of comprehension deficits present in Wernicke's aphasia. Individuals with Wernicke's aphasia are responsive to semantic priming as assessed by a lexical decision task, though they do display more errors than their neurotypical peers (Blumstein, Milberg, & Shrier; 1982; Milberg, Blumstein, & Dworetzky, 1987). Blumstein and Milberg (1999) proposed that the language processing deficit observed in this population reflects either a lower threshold for lexical access or overactive activation (i.e., many concepts are activated and subsequently accessed simultaneously). A lower threshold of activation means that poor exemplars of a category can still result in strong activation of that category (Blumstein & Milberg, 1999). This can result in reduced ability to inhibit related, but irrelevant or off-topic content. Research has shown that individuals with Wernicke's aphasia have difficulty inhibiting responses when presented with related lexical competition (Janse, 2006; Yee, Blumstein, & Sedivy, 2008). An overactive system would account for both production and comprehension deficits observed in Wernicke's type aphasia because it would suggest that many potential lexical candidates were accessed simultaneously. This would result in fluent, incoherent output and poor comprehension, as well as increased errors during a lexical decision task. Clinically, this indicates a need to limit the number of related lexical choices used to cue a response because a larger array of cues may overstimulate the system and prevent retrieval of the target response.

Collectively, priming studies of persons with aphasia have shown that lexical knowledge is not necessarily lost following injury, though access may be altered. For individuals with Wernicke's aphasia, the neural system may be overactive; whereas for individuals with Broca's aphasia the system may have decreased activation and reduced semantic processing leading to decreased verbal output. Collectively, research from both populations have provided sufficient evidence that the neural system is responsive to related content. In the next section, we will discuss priming and cueing with the goal of dissecting the similarities and differences between them providing a theoretical foundation for how cueing stimulates neurobehavioral responses.

The Clinical Cue and the Experimental Prime

Up to this point, we hoped to have established that in the cognitive sciences facilitation of a faster and more accurate response to a target stimulus is frequently achieved through priming, which occurs without need of conscious engagement of retrieval processes. Priming is not routinely discussed as a clinical tool, though it is frequently employed in research to facilitate retrieval, direct attention, and appraise conceptual storage (McNamara, 2005; Sohlberg &

Turkstra, 2001; Tulving & Schacter, 1990). In experimental psychology, it is common for information aiding an individual in completing a task to be described as a prime, whereas the term ‘cue’ may refer to a signal indicating when a task is to be completed (Sudevan & Taylor, 1987; See Figure 6). This differentiation was not intended to distinguish the two (primes versus cues) clinically. Indeed, ‘cues’ in clinical settings are thought to engage cognitive processes in a similar manner as experimental primes.

{Insert Figure 6}

Experimental priming performed by cognitive scientists and cueing performed by clinicians during cognitive and linguistic interventions are intrinsically linked, yet remain two distinct concepts. We have discussed priming in some detail and will now delve into cueing, its clinical efficacy, and how creating a state of heightened awareness is connected with the enhanced behavioral responses attributed to primes. Notable similarities and differences will be detailed.

Cueing is a technique of facilitation used in cognitive-linguistic treatment to aid the retrieval, production, and/or comprehension of targeted information. Use of cues is dependent on a number of factors including: level of severity of the injury, types of deficits, targeted response, client stimulability, and the treatment protocol. Commonly, cues are response-contingent, meaning that the support given to facilitate retrieval is provided following a failed attempt to produce the target response. Semantic, phonological, and orthographic cues have all been effectively used to aid oral-verbal language production in special population such as persons with anomia (Nickels, 2002). Response-contingent cueing, unlike priming, is adapted to the client based on his/her ability to produce the expected response. That is, that cues are often tailored to individual needs. When response contingent cueing is used during cognitive-linguistic intervention, it is common for clinicians to verbally or visually cue a client to produce a target response. Failure to produce the target may lead to the presentation of a cue to help facilitate the target response. Increased success with production results in a reduction in the amount or level of cueing.

Cues are not always response-contingent. They may also occur as a form of prestimulation, in which the target response is presented alongside other potential options before an individual is charged with independently producing the target response (Varholak & Linebaugh, 1995; Linebaugh, Baron, & Corcoran 1998; Wambaugh, Doyle, Martinez, Kalinyak-Fliszar, 2011; Stimley & Noll, 1991). Prestimulation cueing may be active or passive with the former consisting of the participant receiving a prompt containing the target response (e.g., a sentence or picture) and then choosing a response (frequently a picture) corresponding with the presented prompt before later being asked to independently produce (verbally) the target response (Varholak & Linebaugh, 1995). The passive condition requires that the participant only view or listen to a prompt containing the target response and the response options. They do not need to choose a response before being asked to produce the target response (Varholak & Linebaugh, 1995). Prestimulation cueing occurs in a manner similar to priming. The primary difference is prestimulation cueing is used as a precursor to an overt response (e.g., state the name of object) triggering retrieval of the target information. In contrast, primes are engaged passively, not necessarily requiring an explicit response as discussed earlier. Response-contingent cues tend to be used hierarchically, with cues ranging from lower level (i.e., minimal support) prompts to produce a given target (e.g., name these objects), to midlevel cues (i.e., moderate support) such as sentence completions (e.g., 'He ate peanut butter and ______'), and even to high-level cues (i.e., maximal support) such as the clinician producing the desired response and requesting a repetition of the target (Linebaugh, Shisler, & Lehner, 2005; Wambaugh, 2003). The level of the cueing hierarchy used is generally based on what Bollinger and Stout (1976) refer to as "stimulus power" or the level of facilitation needed from a clinician to trigger an accurate response.

It must be noted that use of cues is pertinent to many areas of language intervention. They may be used to facilitate a dialogue—a way to keep the conversation progressing, while not explicitly providing the word to a person with aphasia (Kagan, 1998). They may also be used as a vehicle to initiate successful information acquisition in treatments such as errorless learning. In treatments such as errorless learning, the goal is for the target to be produced correctly on the first trial and on all subsequent trials with the rationale that inaccurate responses may interfere with the learning process (Evans et., al., 2010; Schuchard & Middleton, 2018). Cues, in this case, are a training condition used to facilitate successful acquisition (Schuchard & Middleton, 2018).

As with priming, a specific type of content serves as the cue to facilitate retrieval, with semantic content commonly utilized to elicit a response. Semantic cues are used in language and cognitive rehabilitative treatments to enhance retrieval processes that have been damaged due to neurobiological disease or neurological trauma. Semantic cueing functions by activating related semantic representations underlying the target response. Semantic features are postulated to be pertinent to neural network organization and retrieval in both priming (Cree, McRae, & McNorgan, 1999; McNamara & Holbrook, 2003) and cueing (Linebaugh, Shisler, & Lehner, 2005). Behavioral interventions that are successful in supporting neural changes and cognitive recovery do so by specifically targeting the behavioral deficit with repeated trials that are salient and can induce transference (Kleim & Jones, 2008).

As part of behavioral intervention, cueing likely helps enhance the neural mechanisms supporting cognitive-linguistic processes by either reengaging the network or by recruiting other areas to compensate for the areas in the network that are no longer functioning properly. Multiple studies have shown semantic cues to be effective in aiding individuals with TBI and aphasia with word retrieval and production (e.g., Coelho, McHugh, & Boyle, 2000; Linebaugh, et al., 2005; Wambaugh et al., 2001; Wambaugh, 2003). For example, Cameron and colleagues (2006) used a hierarchical semantic and phonological cueing treatment, which consisted of providing individuals with aphasia with response-contingent cues to aid the lexical retrieval of content absent from elicited story narratives. The level of cueing provided was contingent upon the error produced by the individual. Positive responses were observed for four of five participants providing further efficacy for the systematic use of cueing in aphasia treatment.

Differences between primes and cues appear minimal at the surface level, particularly when the task involves displaying semantically related information and then requesting that an individual respond to a target word or image. In these instances, priming, which is typically thought of as an implicit unconscious or semi-aware phenomenon, is retooled as a cue, a mechanism used to aid improvement of conscious linguistic production and comprehension. Distinctions between the two are restricted to the length of presentation (priming is commonly much shorter; see Automatic Activation vs. Strategic Processing), and to the type of response requested (e.g., implicit is more common for priming tasks and explicit for cueing) with both likely to influence the behavioral response following presentation.

Measures of success for cueing in cognitive-linguistic intervention differ substantially from those in a typical priming experiment because intervention is typically targeted towards improving volitional engagement of cognitive processes. Tasks such as free recall and word recognition are considered explicit because they require intentional conscious recollection of previously encoded information (Roediger, 1990; Schacter, 1987; See Figure 2). Similarly, object naming and phrase completion exercises (e.g., "The dish ran away with the ____") are also explicit, typically requiring intentional cognitive engagement. Thus, cueing can occur in a manner similar to priming, but more commonly necessitates the need for an intentional-explicit response. Priming typically entails response that is not dependent on conscious recollection.

Automatic Activation vs Strategic Processing.

Factors influencing behavioral responses are not limited to intentional cognitive engagement by the participant. For example, the length of stimulus presentation can significantly affect how information is processed. In cognitive-linguistic interventions, cues are frequently presented over the course of seconds and are used as deemed clinically necessary to facilitate a target response. In contrast, primes are presented for fixed amounts of time with the duration of presentation substantially altering the way in which the primes are processed. Primes presented with a short duration (i.e., < 250ms) are believed to trigger automatic, subconscious processes that attend to the target and encode it into the neural system without any purposeful intent or conscious awareness on the part of the individual viewing the stimulus (Neely 1977; Deacon, Uhm, Ritter, Hewitt, & Dynowskaa, 1999). This is referred to as automatic activation.

Automatic activation is frequently discussed with respect to spreading activation theory (Collins & Loftus 1975; Toro, 2000). The faster behavioral response to a presented target is the result of an encoded stimulus, the prime, triggering activation of the target and all related associates located near it in memory (Toro, 2000). Additionally, the shortened presentation of the prime can limit attentional demands and reduce the need to inhibit other stimuli (Posner & Snyder, 1975; Neely, 1977).

Strategic processing, on the other hand, occurs when an observer engages with a prime long enough for it to be brought into conscious awareness, resulting in the facilitation of additional cognitive processes that alter the manner in which the encoded stimulus is processed (McNamara, 2005; Neely & Keefe, 1989). “Semantic matching” is an example of strategic processing in which the meaning of the prime is examined in comparison to the meaning of the target (e.g., presentation of the prime word “bird” and the target word “chicken” will result in retrieval of shared qualities between the two words, such as “feathers”; Neely, 1977; Neely & Keefe 1989). An alternative strategy to semantic matching is “expectancy” in which a participant produces potentially related targets in response to the prime (e.g., presentation of the prime word “bird” is likely to result in retrieval of related words such as “chicken” “duck” “egg” in anticipation of the target word; Neely Keefe, & Ross, 1989; Posner & Snyder 1975). Both strategies can be triggered by prolonged exposure to a prime. Strategic processing in the context of prime exposure refers only to immediate interactions with the prime. It is not referring to metacognitive strategies, which may be triggered due a variety of reasons including, but not limited to insight into task expectations (e.g., monitoring for patterns on a lexical decision task in hopes of identifying when semantic pairs are shown), resources allocated to a task, effortful processing, or previous success with a learning strategy (Efklides, 2010; Pennequin, Sorel, & Mainguy, 2010; Phatiki, 2003). Presenting a prime may engage strategic response, but this is still likely to be influenced by the task and the participant.

The distinction between strategic and automatic processing is pertinent when comparing primes to cues because a clinician may present cues until a client attempts a response. This can be a substantially longer amount of time than the length of the presentation of primes, which are typically displayed for a set time period (e.g., 250 ms), not for an indefinite amount of time.

Therefore, cues presented during intervention are likely to engage strategic processes that may be aiding a client's response.

Priming, Cueing, and Cognitive Reengagement

At this point, we have established that both primes and cues can be used to facilitate responses using similar means. Fundamental differences between the two are linked to timing, engagement (explicit or implicit), and type of response requested (passive or active). Both priming and cueing trigger the retrieval of conceptual knowledge resulting in faster and more accurate responses. The requirement of an active response is the distinction of note because it is through frequent elicitation of the targeted response in contextually relevant exercises that substantial recovery occurs (Kleim & Jones, 2008; Langhorne, Bernhardt, & Kwakkel, 2011). Priming that occurs without activation of explicit retrieval processes is not likely to result in recovery, but may be a sufficient stepping-stone to begin the rehabilitative process.

One of the underlying goals of cognitive rehabilitation is to reengage processes damaged by injury. Priming activates the cognitive-linguistic system with minimal initial volitional cognitive engagement by the client. In theory, priming should tap into the neurological system prior to having a client participate in tasks that require an explicit response, aiding cognitive processing. Because the initial engagement of the system is accomplished by the prime, production and retrieval of explicit target information is made easier. Priming alone is likely to have minimal to no effect on performance of explicit tasks (Roediger & Challis, 1992). Priming would need to be included with exercises targeting intentional cognitive engagement for it to substantially aid the recovery of individuals who have sustained neurological impairment. By incorporating priming as part of an intervention that directly engages explicit memory neurobiological systems, it is expected that, over time, the system will become less dependent on the primes in the same way persons affected by acquired brain injury may become less dependent on cues. Like cues, presentation of primes would gradually be reduced as behavioral performance improves indicative of a recovering cognitive-linguistic system. Priming could be used in conjunction with, or as a precursor to cognitive-linguistic interventions to help engage the neural system for the task at hand. In many cases, these are exercises targeting lexical access, though they may also be tasks of attentional control, memory, or metacognitive strategy use.

Priming-Based Interventions

Priming evidence and theory have been key factors influencing several different language interventions. Two of the most researched and frequently used interventions grounded in priming theory are Semantic Feature Analysis (SFA) and Verb Network Strengthening Treatment (VNeST). SFA and VNeST target improvement of functional communication through activation of related neural network information paired with frequent intentional explicit productions of target responses (See Figure 7). SFA, originally coined Feature Analysis (Ylvisaker, Massaro, & Cohen, 1987), was developed based on Anderson's (1983) theory of spreading activation with production of semantically related features theorized to facilitate more fluid retrieval of related information (Massaro & Tompkins, 1994). During intervention, participants are asked to produce semantic features of a target object (e.g., function, location, action, etc.) with the production of each feature theorized to help facilitate the engagement of related concepts (Boyle & Coelho 1995; Massarro & Tompkins, 1994). The intervention has been shown to be successful in persons with aphasia and TBI, resulting in improved naming of trained objects with varying success for untrained objects and lexical retrieval during discourse tasks (e.g., Antonucci, 2009; Boyle & Coelho 1995; DeLong, Nessler, Wright, & Wambaugh, 2015; Kiran & Johnson 2008; Massarro & Tompkins, 1994).

{Insert Figure 7}

VNeST (Edmonds, Nadeau, & Kiran, 2009) was developed, in part, based on research identifying that priming of verbs results in enhanced production of nouns thematically related to the facilitatory verb (Ferretti, McRae, & Hatherell, 2001). The ability to prime thematically related targets is theorized to be indicative of thematic roles being linked to stored conceptual knowledge (Ferretti et al., 2001). Participants receiving VNeST are trained using transitive two-place verbs (i.e., the verb takes two arguments, an agent and object; e.g., 'The captain drives the boat'). Participants are presented with target verbs and asked to produce multiple sentences containing thematically related agents and objects corresponding to the verb. The intervention encourages expansion of the semantic network by having participants respond to Wh-questions related to one of their produced sentences and having them make semantic judgements about sentences using the identified verbs/nouns. VNeST results in changes in performance for trained targets and for *untrained,* but related items with gains attributed to targeting verbs and associated nouns theorized to be highly connected within the same neural network (Edmonds et al. 2009; Edmonds, Obermeyer, & Kernan, 2014). Studies have found VNeST to be effective in improving production at both sentence and discourse levels (e.g., Edmonds & Babb, 2011; Edmonds et al., 2014a; Edmonds, Mammino & Ojeda, 2014; Furnas & Edmonds 2014).

The success of SFA and VNeST has led to increased interest by treatment researchers to use linked content as a means of strengthening the neural system following injury. For example, Phonological Component Analysis (PCA; Leonard, Rochon, Laird, 2008) is a more recently developed language intervention using the same format and underlying theory established by SFA. Word retrieval is treated using phonological features (e.g., first sound, rhymes, last sound, etc.), rather than semantic features, utilizing similar protocol steps. The phonological features are intended to bring the activation of the target lexical item to threshold. Studies examining the use of PCA have reported positive treatment effects for naming of treated items (Leonard et al., 2008; van Hees et al., 2013), suggesting that targeting linked phonological content can improve the underlying processes supporting lexical processing. Recent findings, however, suggest that although PCA was developed as a phonological equivalent for SFA, the underlying mechanism of may not be strengthening the phonological network in the same manner that SFA is believed to be strengthening the semantic network (Bunker, Mauszycki, Poss, Kallhoff, & Wambaugh, 2019). Additional research is needed to better dissect the mechanisms underlying change in these interventions and to identify how type of naming error produced (e.g., semantic or phonological paraphasia) should influence treatment protocol.

Several studies have examined the facilitatory effects of priming in manner that may benefit intervention research. A study of naming facilitation in aphasia revealed that use of contextual priming (repeated exposure to target objects that are semantically or phonologically related to one another) resulted in improved naming, but only the semantically related stimuli displayed generalization beyond untrained items (Renvall, Laine, Laasko, & Martin, 2003). Martin and colleagues (2004) expanded on this work by examining how contextual priming influenced the verbal production of eleven individuals with varying types of aphasia. Participants were asked to produce names for a series of pictures that were related either semantically, phonologically, or had no relationship. Individual responsiveness to the procedure was highly variable, but overall the researchers found contextual priming resulted in immediate interference in naming, likely due to increased competition between neighboring stimuli. This was followed by a facilitatory effect in production when there was a brief time delay (i.e., the participant was asked to name items again after five minutes) for both phonological and semantic contexts. They noted that priming of semantic contexts led to more immediate interference than phonological contexts, which may be due to the number of semantic representations that are triggered when presenting semantic information.

Concerning the facilitatory effect, a similar result was observed with the use of masked repetition priming in which the prime was not intended to be noticeable to the participant and shown quickly (e.g., ≤ 50 ms). Masked repetition priming aided individuals with anomia in verbally producing target objects, though generalization was not strongly observed (Silkes, 2015). Nonetheless, collectively, these studies provide some indication that priming is reengaging the semantic/phonologic networks and supporting enhanced production in populations with acquired language disorders.

Thus far, this review has primarily discussed priming at the word level. This is because lexical priming has a direct link with how cueing is often used in clinical practice. This is not the only area of priming which can improve our understanding of linguistic production. Syntactic priming (also referred to as structural priming), in which sentences displaying similar grammatical structures and forms are presented to a participant has also been successfully utilized as an intervention tool to facilitate retrieval. Thompson and colleagues (2003) used a sentence production priming-paradigm to examine the role of language complexity in language intervention. Participants in the study were individuals with agrammatic aphasia. The treatment consisted of having participants identify aurally presented target sentences corresponding with a visual stimulus. They were then engaged in a syntactic priming paradigm where the target syntactic structure was modeled for them by the examiner using a foil visual stimulus. Following the presentation of the model, the participant was asked to produce a sentence with similar syntactic structure for the target sentence. They found that treating complex sentential forms resulted in greater generalization to less complex sentence structures.

Priming and Inhibition

Up to this juncture, we have discussed priming solely with respect to its facilitatory properties. We will now provide a cursory overview of negative priming (also referred to as inhibitory priming) with the goal of further aiding clinical decisions regarding how best to tailor cues and primes. While enhancing the likelihood of retrieving a target response may be the desired effect of priming, stimulus presentation can also involve the inhibited retrieval of other responses. Depending on the target response, this can be an unwanted effect, hence the term 'negative priming.' For example, Tipper (1985) found that when participants were instructed to focus on only one of two superimposed objects (differentiated by color), subsequent naming of the attended-to object was facilitated, while subsequent naming of the ignored object reflected a prolonged response latency, reflecting inhibition of the selection of an internal [semantic] representation. The differences in response times suggest that when multiple items/objects are presented together, retrieval of every corresponding semantic representation may not occur, depending on the attentional foci of the individual processing the stimuli.

The focus of attentional resources seems to be of particular importance in the observance of negative priming. Research examining semantic priming and attention allocation revealed that simply providing participants with instructions guiding their attention to a prime was linked with facilitating a primed response; conversely, instruction directing participants to ignore primes was linked with negative priming (Ortells & Tudela, 1996). During stimulus processing, content identified as pertinent may become more [consciously] salient. Information deemed irrelevant may be discarded or potentially inhibited, so as to reduce distractions. Evidence of the differential effects of priming due to the allocation of attentional resources indicates that attentional processes play a key role in role in cognitive engagement and response retrieval. This has implications for which stimuli should be used and how individuals are engaging with stimuli. Not only might a clinician or investigator inadvertently inhibit a target response by having a complex or dense stimulus, he/she may negate positive priming effects if the individual's attention is not directed at an appropriate target (whether spontaneously or cued). If not carefully considered, both primes and cues are likely to have a reduced benefit or even be inhibitory.

A second factor that may negatively influence priming is neighborhood density. A prime that shares a high number of orthographic or phonological neighbors with the target stimulus/response (i.e., have a number of related words with similar spellings or sounds) is more likely to impede the response to the target word rather than facilitate it (Davis & Lupker, 2006; Dufour & Peereman, 2003). Semantic relationships between primes and targets (i.e., the prime competes with the target) can also interfere with retrieval (Howard et al, 2006; Wheeldon & Monsell, 1994). In fact, semantic interference can even be observed when the semantically related prime occurred several trials previous (Howard et al, 2006; Wheeldon & Monsell, 1994). Collectively, these findings suggest that it is important to consider the semantic relationship and/or the orthographic/phonological overlap of cues and primes and their corresponding or subsequent target responses. Careful planning is important to reduce the likelihood of impeding retrieval processes. If multiple responses are trained in the same treatment session, as is often the case, primes/cues should be critically selected and targets should be distinct from one another, so as to limit possible interference from primes/cues for the other targets.

Limitations

Studies chosen for inclusion in the present review of priming and the relationship it has with cueing were chosen because they exemplified the use of priming as a tool to facilitate production. These studies are not indicative of all work performed directly addressing priming and language intervention, though a literature search does currently reveal limited work in this area with the present work referencing a significant portion of published work. Additionally, the present review only minimally discussed the inhibitory effects of priming. There is ample research in this area making the subject matter too vast to thoroughly cover in the present review.

Conclusion and Future Directions

The goal of this paper was to detail the relationship between priming and cueing, while also providing a theoretical premise for how both likely facilitate improved behavioral performance in persons with neurological injury and disease. Cues serve as a means to access the neural system, bringing targeted conceptual information to a heightened state of awareness and subsequently making information easier to access and retrieve. Primes similarly create heightened awareness and are used as a means of triggering a targeted response. Prolonged exposure to either a prime or a cue is likely to trigger strategic retrieval processes that aid with facilitating a response. Cues more commonly entail the requirement of an overt response. This transforms initial implicit cognitive stimulation into a task engaging both implicit and explicit retrieval processes. The latter of which requires at least a low level of intentional volitional cognitive engagement. The priming literature has revealed that repeated exposure to the same content or related content can shift attention and reduce the number of resources needed to complete a task, while also engaging strategic processes that aid cognitive-linguistic functioning. Furthermore, theoretical work examining semantic processing has observed that related semantic features can facilitate retrieval of related concepts, which can be utilized to help facilitate linguistic processing. Engagement of these retrieval mechanisms during repeated production of the target and related targets may strengthen the neurological network leading to repair. Priming intervention studies have shown success in aiding in behavioral performance with respect to language production. Cognitive-linguistic cueing performed during language interventions is intended to aid network restoration and repair, by in part, activating associated concepts in a manner resembling priming. Differences between primes and cues can be linked to timing and conscious intentional volitional engagement, but note that these differences are task dependent. Primes serve as a template for how to structure cues with adequate length, saliency, and associative strength pertinent to success.

Primes used in the cognitive science literature and cues used in the clinical literature are distinct, but are not far removed from one another. Distinctions in terminology tend to be related to researcher intent, presentation schedule (i.e., when the stimulus is presented within the larger experimental or intervention protocol), presentation duration, and subsequent conscious intentional engagement (e.g., implicit versus explicit tasks). Nonetheless, both primes and cues are believed to trigger retrieval of conceptual content related to target information. Continued research and discussion regarding priming and cueing will further our understanding of how to tailor cues to better engage related concepts and enhance the neural connections that underlie cognitive functioning.

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