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Invited Review

Task dependent lexicality effects support interactive models of reading: A meta-analytic neuroimaging review

Chris McNorgan [a,c,*], Sarah Chabal [a], Daniel O'Young [a], Sladjana Lukic [a], James R. Booth [a,b,*]

[a] Department of Communications Sciences and Disorders, Northwestern University, USA
[b] Department of Communication Sciences and Disorders, The University of Texas at Austin, USA
[c] Department of Psychology, University at Buffalo, The State University of New York, USA

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ABSTRACT

Models of reading must explain how orthographic input activates a phonological representation, and elicits the retrieval of word meaning from semantic memory. Comparisons between tasks that theoretically differ with respect to the degree to which they rely on connections between orthographic, phonological and semantic systems during reading can thus provide valuable insight into models of reading, but such direct comparisons are not well-represented in the literature. An ALE meta-analysis explored lexicality effects directly contrasting words and pseudowords using the lexical decision task and overt or covert naming, which we assume rely most on the semantic and phonological systems, respectively. Interactions between task and lexicality effects demonstrate that different demands of the lexical decision and naming tasks lead to different manifestations of lexicality effects.

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1. Introduction

Reading entails the decoding of visual orthographic representations into a phonological representation. The ease with

* Corresponding authors at: Department of Communications Sciences and Disorders, Northwestern University, USA.
E-mail addresses: cpmcnorg@buffalo.edu (C. McNorgan), j-booth@austin.utexas.edu (J.R. Booth).

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which skilled readers map between these very different representational systems is the product of a great deal of explicit and implicit learning. In alphabetic languages, on which we focus here, a fluent reader will have spent considerable time undertaking explicit instruction in the rules for mapping letters and letter combinations to existing verbal representations (i.e., the alphabetic principle). Models of reading development and disorders agree that phonologically decoding a particular string of letters depends on whether or not those letters map to a word with which an individual is familiar. Lexicality manipulations are consequently an important tool for investigating reading processes. Lexicality refers to whether a letter string represents a word with an associated meaning (e.g., TRAY). Letter strings that do not represent words can be either pseudowords (e.g., TAYR), which are pronounceable strings of letters sharing characteristics of legal words but without an associated meaning, or non-words (e.g., RTYA), which have no associated meaning and additionally violate the spelling rules for a language. Lexicality presumably influences many aspects of language processing and may consequently be investigated using any number of experimental tasks. Of these, however, the lexical decision task (LDT) and naming (overt or covert) dominate the neuroimaging literature (Katz et al., 2012).

1.1. LDT and naming task characteristics

In the context of orthographic processing, the LDT requires participants to indicate whether a given letter string is associated with a real word. Participants are not expected to retrieve or even possess robust semantic representations for these words, but must merely be aware that some such representation exists, and this task has consequently been described as a signal detection process (Jacobs et al., 2003). Not all models of reading agree on the degree to which the LDT relies on semantic knowledge. For example, in the dual route cascaded (DRC) model of reading aloud (Coltheart et al., 2001), lexicality decisions are based on the outcome of a lookup process in the orthographic lexicon, and may proceed even if the semantic system is removed entirely (Coltheart et al., 2010). A contrasting perspective, taken by parallel distributed processing (PDP) models, such as the triangle model (Seidenberg and McClelland, 1989) is that there are no lexicons (Dilkina et al., 2010). Rather, reading in these models is the product of the dynamic interaction of orthographic, phonological and semantic processing systems (Harm and Seidenberg, 2004). The centrality of these interactions to the triangle model of reading, which assumes that skilled reading is the dynamic product of interactions between these systems, suggests this model as a framework for their interpretation. Unfortunately, only one study to date (Harm and Seidenberg, 2004) has fully implemented the triangle model (i.e., containing semantic, orthographic and phonological representational units), and this study did not explore the interaction between task and lexicality. Within the triangle model, the presence or absence of associations between a particular orthographic/phonological pattern and a semantic representation determine the lexicality status of a token. We take the position that the LDT is, by definition, tied to semantic memory, as even in the DRC model, lexical entries exists only for a letter strings with underlying semantic representations. This position is supported behaviorally, as LDT appears to automatically activate semantic representations, if available, though this activation may decay quickly without active maintenance (Neely et al., 2010). Moreover, compared to naming, LDT performance appears to be more dependent on semantic properties of words (Balota et al., 2004; Yap and Balota, 2009). We reiterate for clarity, however, that different models make different assumptions regarding the nature and degree of support that semantic knowledge provides. Within the DRC, for example, the semantic system may provide input into the phonological and orthographic lexicons, providing a basis for semantic priming effects in LDT and naming tasks (Blazely et al., 2005), but it is not strictly required for either task. Moreover, simulations of semantic processing in these tasks within the DRC do not exist. Thus, it is unclear whether the DRC predicts that the LDT should be particularly sensitive to semantic input.

Naming, whether overt or covert, requires participants to transform a given letter string into the corresponding phonological representation, and in the case of overt naming, or "reading aloud", additionally generate the articulatory motor sequences required to verbalize that representation. Because the spelling-to-sound mappings for pseudowords are unfamiliar, reading aloud should be more difficult for these items. The triangle model assumes that naming taps semantic representations, and the neuroimaging literature supports this argument (Binder et al., 2005). However, we assume that naming task performance is more tightly bound to processing within the phono-articulatory system, and this too is borne out behaviorally: Balota and colleagues carried out hierarchical regression analyses of naming and LDT latencies for monosyllabic (Balota et al., 2004) and multisyllabic words (Yap and Balota, 2009). These studies, which examined the influences of phonological (e.g., onset phoneme characteristics), lexical (e.g., orthographic neighborhood size) and semantic (e.g., imageability) features show that phonological features and word length (both characteristics relevant to pronunciation) are more predictive of naming performance, whereas semantic variables were more predictive of LDT performance.

Because only words have associated semantic content, we predict increased activation for words relative to pseudowords in regions implicated in semantic processing, most pronounced for the LDT. Conversely, we predict increased pseudoword activation in phono-articulatory areas, reflecting the increased difficulty in making spelling-to-sound mapping for these items, and this should most pronounced in naming.

To our knowledge, only Carreiras et al. (2007) have explored task by lexicality interactions, finding some evidence that lexicality effects are modulated by task. Naming was associated with greater left precentral gyrus activation than the LDT for the [Pseudowords > Words] contrast, which the authors argued reflects non-semantic phonological retrieval for pseudowords. This supports the argument that naming more strongly taps phonological processes and that these activations should be stronger for pseudowords. However, the LDT was associated with greater right inferior frontal gyrus activation (IFG) for words, which they argued reflected response inhibition for pseudowords, rather than semantic activation for words. Because processes related to response selection and attention have not been modeled within the triangle model, we will not speculate on this result. Carreiras et al. did, however, find greater activity for words than for pseudowords in a middle temporal region implicated in semantic processing (Binder et al., 2009) that was numerically greater for LDT. This leaves open the possibility of a subtle task by lexicality interaction within this region, or that the items used in this particular experiment were not ideally suited for eliciting robust semantic activation. A meta-analytic review of task and lexicality effects may thus reveal semantic-processing related interactions between lexicality and task in middle temporal regions.

1.2. Previous meta-analyses of lexicality effects

Reading in alphabetic languages involves the coordination of a network of brain regions that, broadly speaking, play specialized roles in supporting orthographic, phonological and semantic processing. The role of individual or networks of brain regions underlying these processes has been studied in great deal. Orthographic processing is attributed to bilateral occipitotemporal