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Localizing Damage in the Functional Architecture: The Distinction between Implicit and
Explicit Processing in Deep Dyslexia

by

Annette Colangelo

A Dissertation
Submitted to the Faculty of Graduate Studies and Research
through Clinical Psychology
in Partial Fulfillment of the Requirements for
the degree of Doctor of Philosophy at the
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Abstract

Deep dyslexia is an acquired reading disorder in which a previously literate adult produces semantic errors during reading and demonstrates impaired nonword reading. Most models of the syndrome account for the reading errors observed in deep dyslexia in terms of multiple loci of damage. In contrast, Buchanan, McEwen, Westbury, and Libben (2003) proposed that reading errors result from damage in the phonological output lexicon alone. According to this formulation, semantic errors result from impaired explicit access and production due to failure of inhibition. In contrast, implicit processing is assumed to be intact in deep dyslexia. In the current manuscript, I tested several predictions that develop from the Failure of Inhibition Theory in order to localize damage in the functional architecture of the language system.

To My Family, with love and gratitude

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INTRODUCTION

The adequacy of explanations for neuropsychological phenomena hinges upon the theoretical sufficiency of the models from which they are derived. In order to refine accounts of various disorders, the assumptions upon which these models are predicated must be rigorously tested and revised to accommodate novel research findings. With respect to language disorders, the basic assumption underlying cognitive models of different acquired dyslexias is that impairments reflect the operation of remaining linguistic components after damage to the functional architecture. How this breakdown is conceptualized depends on the manner by which lexical information is assumed to be represented in the language system.

Language Representation and Information Processing in Normal Reading

Although conceptualized differently depending on the model, most accounts assume normal reading is a multi-step process that is mediated by the spread of neuronal activation from one level of word (lexical) representation to the next: The processing of words involves visual analysis of the printed form, which results in *access* to entries in the orthographic lexicon (i.e., the ‘mental dictionary’ that contains the spelling descriptions for words in the reading vocabulary, known as orthography). Subsequently, orthographic information feeds into the semantic system (i.e., the ‘mental dictionary’ that contains word definitions) to *access* the meaning of words. Semantic entries then *access* the phonological lexicon (i.e., the ‘mental dictionary’ that contains sound specifications for words, known as phonology) where activation supports an oral response. Within this framework for lexical processing, access at each level of representation (i.e., orthography, semantics, and phonology) can be understood as the point at which entries associated with

presented information are activated (e.g., for the semantic system, at the point that the definition for a printed word is activated).

Models of Skilled Reading

Theories of normal reading are similar insofar as they posit different storage systems for linguistic information (e.g., orthographic, semantic, and phonological information). However, they differ in the manner in which this information is represented and accessed. Although hybrid models exist, current theories of skilled reading can generally be divided into two broad categories: dual and single route models. In dual-route accounts (e.g., Coltheart, Curtis, Atkins, & Haller, 1993; Patterson & Morton, 1985), the conversion from orthography to phonology can occur by either of two possible routes: the assembled and addressed routes (see Figure 1). The assembled route (pathway A) uses rules regarding the relationship between letters and sounds to sequence sound segments (i.e., phonemes) in order to develop a pronunciation. Because regular words (e.g., *save* and *wave*) reflect these rules, the assembled route can produce their correct pronunciations. However, exception words (e.g., *pint*) have atypical spelling-to-sound correspondences and therefore violate these rules. Consequently, processing of exception words via the assembled route does not yield correct pronunciations. Thus, this route cannot process words by directly accessing its meaning in the semantic system. However, it can read nonwords that reflect typical spelling-to-sound correspondences.

The addressed route (pathway B) relies on previous experience with letter strings, which results in the formation of whole-word representations in the orthographic lexicon. Providing that the system has encountered the printed word before, its orthographic representation is activated. Once the orthographic representation is activated, it accesses

the corresponding meaning in the semantic system. The semantic representation then proceeds to the phonological output lexicon, which supports the production of an oral response (i.e., the aloud reading response). Because exception words are represented in the orthographic lexicon (i.e., the system has previously encountered them), they can be processed via the addressed reading route. Thus, although the addressed reading route cannot process nonwords, it can process words associated with semantic information.

It is important to note that dual-route theories of reading are explicitly localized in their representations: Each unit in the architecture codes for distinct pieces of information. For example, one processing unit in the semantic system may contain all the meaning information related to the “cat” representation. As described above, these models conceptualize access to information in terms of a serial-ordered mechanism that

uses either a rule-based (rules express general grapheme-phoneme correspondences) or a memory-based strategy (whole entries are stored in memory based on previous experiences with the unit).

Seidenberg and McClelland (1989) presented an alternative to the dual-route theories by proposing that normal reading is accomplished via a single route involving interactions between orthography, semantics, and phonology. Each unit in the system contributes activation to many different representations that are accessed simultaneously via a network of interconnections and back propagation. Thus, according to parallel-distributed processing (PDP) models or “connectionist” networks, word knowledge is not represented in discrete entries that are serially accessed. Instead, information is distributed throughout the network, accessed in parallel, and is stored as a pattern of activation across units resulting from “experience with the spelling-sound correspondences implicit in the set of words from which it learns” (p. 525). For oral reading to proceed, the orthographic pattern of activation representing a word produces the pattern of activation that corresponds to that word across nodes at the semantic level. In networks that include a layer for phonology, the pattern of semantic information activated by orthographic input activates the pattern of nodes representing the phonology of the word.

PEIR: A Model to Study Deficits in Neurolinguistic Patients

Given that word production is generally acknowledged to be a multi-step process, lexical processing can potentially be compromised at different theoretical levels. Buchanan, McEwen, Westbury, and Libben (2003) introduced a framework for studying word production deficits in neurolinguistic patients, called PEIR. This model

acknowledges the distinction between word entries and access to those entries. According to the PEIR formulation, word production depends on explicit access, which depends on implicit access, which in turn depends on intact representations (e.g., the specific entries representing word meanings in the semantic system). Within this framework, Buchanan et al. (2003) proposed that production errors (e.g., making semantic errors during aloud reading of a single word) reflect compromised explicit access. Explicit access refers to overt knowledge regarding relevant orthographic, semantic, or phonological characteristics of words. For example, with respect to explicit access in the semantic system, the ability to correctly judge that *horse* is more related in meaning to *saddle* than *house* depends on the ability to overtly compare word meanings. Because damage is only posited at the level of explicit access, implicit access to intact representations is assumed to be preserved. Implicit access is conceptualized in terms of sensitivity to orthographic, phonological, or semantic manipulations without requiring explicit access or production. For example, sensitivity to semantic manipulations can be indexed in terms of faster responses to name a word like *table* or to decide whether it is a word when it is preceded by *chair* rather than by an unrelated word, even in the context of not being able to overtly decide whether *table* and *chair* are semantically related.

A fundamental goal of word recognition research is to specify the functional architecture of the mental lexicon and to adjudicate between various theories of lexical representation and processing. A powerful test of word recognition models hinges upon the performance profile that emerges when putative components within the language system are damaged and factors presumed to impact linguistic mechanisms are varied. Selective reading impairments are assumed to reflect damage within different

subcomponents of linguistic processing (e.g., orthographic lexicon, semantic system, phonological output lexicon). Thus, functional analysis of lexical performance associated with acquired reading disorders offers a privileged opportunity to elucidate the organization and structure of normal reading.

Reading Disorders

Most reading disorders that result from brain damage are broadly classified into three categories (Buchanan, Hildebrandt, & MacKinnon, 1999): surface dyslexia, phonological dyslexia, and deep dyslexia. Patients with surface dyslexia are able to sound out letter strings based on rules for spelling-to-sound correspondences but are unable to access whole word representations from print (Marshall & Newcombe, 1973). Consequently, aloud reading for regular words (i.e., words with common spelling-to-sound correspondences, such as *gave*, *save*, and *cave*) and nonwords (i.e., nonsense letter strings that can be decoded based on rules for spelling-to-sound correspondences, such as *frip*) is intact. However, surface dyslexics read exception words incorrectly because these words have irregular spelling-to-sound correspondences (e.g., *have*). Instead, they *regularize* exception words by applying the rules for typical pronunciations. For example, surface dyslexics pronounce the word *have* such that it rhymes with *gave*, *save*, and *cave*.

In phonological dyslexia, patients are able to access the meaning of whole word representations from print, but are unable to assemble sound segments that correspond to word spellings (Beauvois & Derouesne, 1978). As such, phonological dyslexics are able to read familiar words, including regular and exception words. However, these patients are unable to successfully read aloud nonwords.

Deep dyslexic patients are similar to phonological dyslexics insofar as both patient groups are unable to successfully read aloud nonwords. However, deep dyslexic patients also demonstrate impaired whole word reading (Marshall & Newcombe, 1973). Impaired reading for words includes visual errors, derivational errors, as well as semantic errors. Given that these patients show multiple reading impairments, deep dyslexics are assumed to have a form of reading disorder that is central to the reading system. This dissertation focuses on the syndrome of deep dyslexia with a particular emphasis on the production of semantic errors during aloud reading.

DEEP DYSLEXIA

The Symptom-Complex of Deep Dyslexia

Deep dyslexia is an acquired reading disorder in a previously literate adult. Given the relative homogeneity of reading deficits in most patients with deep dyslexia, the disorder is considered a syndrome (Coltheart, 1980a). The defining symptom of deep dyslexia is the production of semantic errors during aloud reading. Semantic errors are defined as incorrect naming responses that relate to the target in meaning (e.g., *tide* → *water*). Although semantic errors are the hallmark symptom, deep dyslexics also produce other types of reading errors. For example, visual errors occur when the response resembles the target in terms of shared letters (e.g., *gallant* → *gallon* and *perform* → *perfume*). In addition, some errors reflect substitutions of one function word for another in the same class (e.g., *for* → *and*), termed function-word substitutions. Derivational errors result when the target and response differ only in terms of bound morphemes (e.g., *sick* → *sickness*)¹. These types of errors co-occur with semantic errors frequently and are therefore considered part of the symptom-complex (see Coltheart, 1980a for a comprehensive discussion of error types and the symptom-complex in deep dyslexia).

In addition to types of errors produced, deep dyslexia is defined by an inability to read aloud nonwords (i.e., nonsense letter string). Typically, these patients also demonstrate effects for concreteness (better reading of high-imageability, e.g., *cat*, than low-imageability words, e.g., *happy*), syntactic category (better reading of nouns than adjectives, which are easier to read than verbs), and word class (better reading of content,

¹ A morpheme is the smallest unit containing linguistic meaning (e.g., *-ed*, *cat*, *-ness*, *baby*, *un-*, etc.). Morphology is the description of the word form in terms of morphemes (Reisberg, 1997). Although important for a comprehensive understanding of linguistic processing in deep dyslexia, further discussion of morphology is beyond the scope of this paper.

e.g., nouns, than function words, e.g., *for*, *the*, etc.) during oral reading (Coltheart, 1980a).

Accounts for Deep Dyslexia

Several models have been proposed to account for deep dyslexic reading performance. The following section presents a brief review of models for deep dyslexia with an emphasis on the manner in which these frameworks conceptualize the occurrence of semantic errors and the inability to read aloud nonwords.

The Dual Route Account: The Morton and Patterson Model

In order to account for both the occurrence of semantic errors and the inability to read aloud nonwords, Morton and Patterson (1980) postulated that deep dyslexia reflects multiple loci of damage within the dual-route model for reading. To explain the inability to read aloud nonwords, this model proposes that the assembled route is unavailable in deep dyslexia. As a consequence, deep dyslexics are assumed to lack the capacity to assemble phonology. Instead, reading is assumed to proceed through the semantically mediated addressed route. Normally, the addressed route is capable of supporting normal reading through whole word access. However, based on the fact that deep dyslexics produce semantic errors during reading, damage to this route is also assumed.

The Continuum Account: Phonological and Deep Dyslexia

Glosser and Friedman (1990) proposed that deep dyslexia and phonological dyslexia represent endpoints along the same continuum of reading disability (also see Laine, Niemi, & Marttila, 1990; Sartori, Barry, & Job, 1984). This conceptualization is based on reports of patients with deficits that were initially consistent with a diagnosis of deep dyslexia, but that evolved over time to a pattern of impairment associated with

phonological dyslexia (e.g., see Glosser & Friedman, 1990; Klein, Behrmann, and Doctor, 1994; Southwood & Chatterjee, 2001).

Similar to the dual-route model, the view articulated by Glosser and Friedman (1990, 1996) assumes that errors in semantic deep dyslexia reflects damage to the semantic system, whereas impaired nonword reading reflects damage to the nonsemantic reading route. However, in contrast to the dual-route model, which assumes that subword phonology is assembled according to spelling-to-sound correspondences, Glosser and Friedman (1990, 1996) argued that reading via the nonsemantic route is accomplished by mapping subword orthographic information *directly* to phonological entries in the output lexicon (i.e., mapping units by comparison, termed analogical mapping). According to this account, evolution from deep to phonological dyslexia reflects recovery of the semantic system and, thus, the disappearance of semantic errors during reading (but see Friedman, 1996 for other analogical aetiologies of recovery). However, nonword reading is still impaired because damage to the direct orthography-to-phonology route does not recover.

The Connectionist Account: Computational Modeling

The connectionist approach to deep dyslexia is based on a computational model of normal reading implemented as nodes interconnected in a parallel distributed processing network (Plaut, 1999). The nodes that comprise the network form layers that represent various features of a word. At each layer, similar words are represented as similar patterns of activity. Plaut and Shallice (1993) produced many deficits analogous to those observed in deep dyslexia by introducing a single lesion to a connectionist network that mapped orthography to phonology via semantics. However, Buchanan et al. (1999) noted that

Plaut and Shallice used connectionist networks that mapped semantic activation directly onto the phonological layer. Given that nonwords have no semantic representation, these networks could not support nonword reading. Buchanan et al. (1999) stated that, to the extent that nonword reading was impossible, the architectures were already dyslexic prior to lesioning. As such, the inability to support nonword reading can "...be likened to a second source of damage in the model... (p. 198)."

The Right Hemisphere Hypothesis: The Neurological Account

The Right Hemisphere Hypothesis proposes that the deficits in deep dyslexia reflect the contributions of the right hemisphere to reading after the dominant left hemisphere has been damaged (Coltheart, 1980b). This view assumes that damage to the left-hemisphere eliminates access to the left orthographic lexicon. In order for reading to proceed, orthographic access to a right-hemisphere lexicon is necessary. However, the right hemisphere cannot subserve the production of language. Therefore, once the orthographic lexicon accesses the semantic representation, it is transmitted from the right to the left hemisphere. This information is then used to access a phonological entry in the left-hemisphere lexicon where a pronunciation is selected and subsequently produced (Coltheart, 1980b; Coltheart, 2001).

The Right-Hemisphere Hypothesis stipulates that how semantic errors develop depends on the type of error. Specifically, semantic errors can either share features with the target (e.g., *dog* and *cat* share many features, including the fact that both have *four-legs*, are *furry*, have a *tail*, etc.) or are associatively related to the target (associative semantic errors do not share features with the target but are related because they co-occur in language, e.g., *next* → *exit* and *merry* → *Christmas*). Shared-feature semantic errors

are assumed to result because a “degree of disparity” is accepted between the semantic representation that is transmitted from the right hemisphere and the lexical entry in the left-hemisphere that is selected for response. In contrast, associative semantic errors are assumed to result from the associative network of the right hemisphere wherein associated entries are co-activated when the target is presented. Errors result from incorrect selection from among activated candidates and the subsequent transmission of that semantic representation to the left hemisphere for production (Coltheart, 1980b; Coltheart, 2001). Although the Right Hemisphere Hypothesis attempts to account for the occurrence of different types of semantic errors, it does not specify the mechanism for semantic errors. In addition, this model assumes that the right hemisphere is completely unable to derive phonology from print. Given the assumption that the right hemisphere mediates the processing of orthographic information in the context of left hemisphere damage, this explanation for deep dyslexia posits an inability to read nonwords.

The Failure of Inhibition Theory (FIT)

Although formulated differently, Buchanan et al. (1999) emphasize that each of the aforementioned models of deep dyslexia assume multiple loci of damage in the reading system (i.e., damage to phonology as reflected by impaired ability to read aloud nonwords and damage to the semantic system given semantic errors during reading). In contrast, Buchanan et al. (2003) proposed that selection impairment due to failure of inhibition in the *phonological output lexicon* alone accounted for the various types of reading errors observed in deep dyslexia. The failure of inhibition theory (FIT) incorporates aspects of both the dual route and connectionist models of normal reading insofar as it conceptualizes lexical access as resulting from spread of activation from one

level of representation to the next through an interactive network of interconnections (i.e., is not completely modular). According to FIT, lexical access in deep dyslexia can be achieved via either the addressed route for real words or the assembled route for unfamiliar words and nonwords.

According to this conceptualization, when a *real word* is presented in print it accesses the addressed route: The orthographic representation for that word is activated in the orthographic lexicon, which in turn activates the representation associated with that word in the semantic system. Graded activation then spreads from the target representation to other representations within its neighbourhood of semantically related entries. For example, the neighbourhood for *cat* defined in terms of semantics might include *dog*, *mouse*, *cheese*, *scratch*, etc. The neighbourhood of semantically related entries is then activated in the phonological output lexicon. Reading errors in deep dyslexia occur because all associated candidate representations (i.e., the neighbourhood) are activated in the phonological lexicon but are not pruned through inhibition, as would normally be the case in an intact system. Therefore, reduced inhibitory connections result in decreased sensitivity to the activation levels of neighbours. This reduced inhibition increases the likelihood that neighbours are incorrectly selected for response.

During normal *nonword* naming, the assembled route is accessed: The subword phonology for the letter string is assembled, which then enters the phonological output lexicon. The assembled nonword phonology then activates associated phonological neighbours (i.e., phonological neighbourhood can be defined as those words that share all but one phoneme with the target). By the method of analogical mapping, the assembled nonword phonology is checked against the phonological candidates of activated

neighbours. Given that there is no lexical entry in the phonological output system for the nonword, this process results in a “nonmatch.” Consequently, the assembled phonology represents the “best guess” of the system. However, in deep dyslexia, an inability to name this assembled phonology results because nonwords provide no semantic lexical activation to boost activation levels of phonological representations. Specifically, nonword naming in deep dyslexia is impaired by the random pattern of activation that results from a failure to inhibit co-activated candidates in the phonological output system. Random activation results in inefficient analogical mapping. As such, the time required to check activated lexical candidates often exceeds the time that the assembled pronunciation can be maintained in memory. As a result, no response can be made. Although the system generally “times out” before activated candidates are mapped to the assembled phonology, the word that has received the most activation (i.e., a close neighbour) may occasionally be chosen. On these trials, a word is offered in response to the nonword (Buchanan et al., 1999).

Toward an Integrated Understanding

The above reviewed models differ on many levels, raising several questions regarding the manner in which the reading deficits in deep dyslexia are best conceptualized: How many systems are damaged (single versus multiple loci of damage)? Where is the level of damage in the language system (e.g., semantic system versus phonological output lexicon)? What is the mechanism for errors (e.g., failure of inhibition)? And, how does language processing and damage map neurologically? To answer these questions, a systematic evaluation of deep dyslexic reading that incorporates consideration for theoretical representation and neurological instantiation is necessary.

Although connectionist networks offer several advantages over modular accounts, particularly with respect to its learning capability and conceivable neuronal instantiation, these models often do not simulate reading impairments well (see Patterson, Seidenberg, & McClelland, 1989). The major strength of the Right Hemisphere Hypothesis is that it postulates neurologically plausible substrates for linguistic processing; but given that it is not based on a model of normal reading, it is difficult to evaluate on a theoretical level. As such, for purposes of the current work, reading will primarily be described within a dual-route framework.

HEMISPHERIC CONTRIBUTIONS TO LANGUAGE

It is generally acknowledged that both hemispheres contribute to the processing of language. However, the left and right hemispheres specialize in different aspects of linguistic information. For example, the left hemisphere has traditionally been assumed to have a local bias in language processing-- more involved in the processing of speech sounds, abstract word meanings, and syntax. In contrast, a global bias has typically been attributed to the right hemisphere--implicated in prosody, as well as the processing of emotional content and gist information. Given different contributions to the processing of language, the left and right hemispheres are assumed to have separate but complementary functions (Beeman & Chiarello, 1998).

Investigations regarding hemispheric contributions to language have primarily used the divided visual field technique with neurologically intact individuals. The divided visual field technique capitalizes on knowledge regarding the anatomy of the visual system and its cerebral projections to isolate stimuli presentation to the right or left hemisphere: Presentation of stimuli to the left visual field projects input to the right, but not the left hemisphere. In contrast, stimuli presented to the right visual field projects input to the left, but not the right hemisphere. By isolating visual input to either the right or left hemisphere, hemispheric contributions to lexical access and the processing of stimuli can be indirectly assessed.

Lexical decision and naming tasks are popular techniques used to index lexical access in divided visual field research. The lexical decision task requires that participants decide as quickly as possible while maintaining accuracy whether a letter string is a word or nonword (e.g., Meyer & Schvaneveldt, 1971 for semantic priming). In naming tasks,

participants are instructed to read aloud presented targets (e.g., Meyer, Schvaneveldt, & Ruddy, 1975 for semantic priming). For both types of tasks, lexical access is indexed in terms of response time (i.e., the time between target presentation and response registration). An important effect for examining lexical access in the system using these tasks is priming. With respect to the semantic system, priming results when response times to items (e.g., *butter*) are faster and more accurate when they are presented after semantically related words (e.g., *bread*) than after unrelated words (e.g., *nurse*). Explanations for semantic priming generally hinge on the assumption that activation spreads to related entries in the semantic system (for reviews, see McKoon & Ratcliff, 1992; McNamara, 1992a, 1992b, 1994). By increasing the activation levels of semantically related items prior to presentation (e.g., partial activation of *butter*, *dough*, *loaf*, *water*, *food*, etc. when *bread* is presented) the spread of activation facilitates lexical access to subsequent items (e.g., *butter*).

Cumulatively, the results from divided visual field studies with neurologically intact participants indicate hemispheric differences during word recognition with respect to the time course of activation for different semantic information (see Appendix 1 for a summary of priming effects over time; for *non-associated category meanings*: Chiarello, 1985; Chiarello, Burgess, Richards, & Pollock, 1990; Chiarello & Richards, 1992; Abernethy & Coney, 1990, 1996; Koivisto, 1997; Collins, 1999; and Chiarello, Maxfield, Liu, & Kacinik, 2001), *semantic associates*: Abernethy & Coney, 1993; Nakagawa, 1991; Coney, 2002; Richards & Chiarello, 1995; Livesay & Burgess, 2003; Chiarello, Burgess, Richards, & Pollock, 1990; Audet, Driessen, & Burgess, 1998; and Chiarello, Liu, Shears, Quan, & Kacinik, 2003, as well as *dominant and subordinate representations of*

ambiguous words: Burgess & Simpson, 1988; Chiarello, Maxfield, & Kahan, 1995; Atchley, Burgess, Audet, & Arambel, 1996; Atchley, Burgess, & Keeney, 1999; and Faust & Lavidor, 2003). Through spread of activation, a broad range of semantic information is initially activated in the left hemisphere, including non-associated category meanings (i.e., word pairs with shared category membership but are not associated with one another, e.g., DEER-PONY are both *animals* but do not occur in similar contexts in language), semantic associates (i.e., word pairs that occur in similar contexts in language e.g., BEE-HONEY or DOCTOR-NURSE), as well as dominant (e.g., the meaning of BANK associated with MONEY) and subordinate (e.g., the meaning of BANK associated with RIVER) representations of ambiguous words (e.g., BANK). At approximately 500 ms, the left hemisphere begins to narrow activation to focus on highly related semantic information. After this temporal interval, the meaning selection and suppression of other potential candidates occurs. Studies investigating hemispheric contributions to the processing of semantic information converge to suggest that selection involves maintenance of activation for highly related meanings, including strongly associated information and meanings consistent with the dominant representation of ambiguous words. In contrast, less likely meanings are actively suppressed, such as non-associated category members and the subordinate meaning of ambiguous words. In the right hemisphere, activation for strongly related semantic information is rapid and sustained. Although activation for more remote concepts is delayed relative to the left hemisphere, this semantic information is maintained at later temporal intervals. For example, activation for non-associated category members emerges in the right hemisphere at approximately 575 ms and is still evident at 750 ms. Given rapid and sustained activation

for strongly related semantic information and the emergence of activation for more remote concepts later in the time course, the right hemisphere appears to sustain activation for a broad range of semantic information over time.

Importantly, the results of semantic priming studies examining patients with focal lesions support hemispheric differences in the activation of semantic information (e.g., Henik, Dronkers, Knight, & Osimani, 1993; Hagoort, 1997; Milberg & Blumstein, 1981; Bushell, 1996; Blaxton & Bookheimer, 1993; Copland, Chenery & Murdoch, 2002). Most notable is the finding that, although patients with left hemisphere lesions showed relatively rapid activation for a broad range of semantic information, these patients exhibited a diminished ability to select among semantically related lexical competitors and inhibit less likely meanings at later temporal intervals: Patients with left hemisphere lesions showed lexical access and spread of activation for strong associates at early temporal intervals. At later temporal intervals, the retrieval of related targets was disadvantaged relative to unrelated targets, which suggests impaired meaning selection when strong associates are activated. With respect to ambiguous meanings, patients with lesions in the left hemisphere showed early activation of both context appropriate and inappropriate meanings. However, these patients were unable to use contextual information to inhibit inappropriate meanings over time. Thus, damage to the left hemisphere appears to disrupt the mechanism responsible for the selection and suppression of semantic meaning. These findings are consistent with the results of divided visual field studies with normal participants implicating the left hemisphere in meaning selection and the active inhibition of irrelevant semantic information.

LEFT HEMISPHERE INHIBITION: CONTROLLED LEXICAL-SEMANTIC PROCESSING

The results from divided visual field studies with neurologically intact participants indicate hemispheric differences during word recognition with respect to the time course of activation for semantic information. The precise mechanism responsible for changes in semantic priming effects over the course of activation is the topic of considerable debate in word recognition research. The lack of consensus in the literature is due in part to the fact that priming effects can be attributed to at least two different cognitive processes: automatic and controlled processes. Automatic processes are assumed to reflect passive spread of activation from one entry to related concepts in the semantic system (Collins & Loftus, 1975). Automatic spread of activation is rapid, occurs without intention or conscious awareness, and is assumed to be evident in conditions at short temporal intervals (i.e., less than 400ms) or a low proportion of related prime-target pairs (Neely, 1977, 1991). In contrast, controlled processing only operates with intention and is assumed to be under the strategic control of the participant. "This mechanism acts by strategically scanning the semantic system in order to select the most relevant of the related nodes, and by inhibiting retrieval of information stored in semantically unrelated nodes (Perri, Carlesimo, Loasses, & Caltagirone, 2000, p. 223)." Controlled processing is typically associated with conditions that encourage attention mediated processes, such as long temporal intervals between the prime and target (i.e., exceeding 500 ms) or a high proportion of related prime-target pairs (Posner & Snyder, 1975). This attention mediated cognitive process is assumed to be responsible for inhibitory effects (i.e., slower response

times to unrelated targets relative to neutral conditions) (Neely, 1977, 1991; Posner & Snyder, 1975).

The distinction between automatic and controlled processing is relevant to understanding hemispheric differences in the activation of semantic information over time. With respect to the left hemisphere, the results from divided visual field studies converge to suggest that a broad range of semantic information is initially activated. That diffuse activation in the left hemisphere occurs rapidly suggests that priming effects at this early stage reflect the passive spread of activation. Over time, the left hemisphere appears to narrow activation to focus on highly related meanings while inhibiting less relevant semantic information. Because selection of highly related semantic information and inhibition of remote concepts manifests only at long temporal intervals (i.e., after 500 ms), priming effects in the left hemisphere at this later stage are likely attributable to controlled processing. Similar to the left hemisphere, broad activation manifests relatively early in the right hemisphere, but activation does not narrow at later temporal intervals. Cumulatively, these results imply that both the left and right hemispheres contribute to lexical access through passive spread of activation. However, controlled processing may primarily operate in the left hemisphere (e.g., Chiarello et al., 1990, 1992).

Given evidence for both automatic and controlled processes in the left hemisphere at different time points, the distinction between implicit and explicit lexical access as articulated by Buchanan et al. (2003) is also applicable to findings of divided visual field research. Specifically, because early priming effects (i.e., less than 400 ms) are assumed to reflect automatic processes, improved performance at this stage is attributable to passive spread of activation in the semantic system. Spread of activation results in higher

activation levels for related relative to unrelated entries in the semantic system. Therefore, facilitation mediated by automatic processes reflects implicit lexical access as indexed by sensitivity to the relative activation levels of semantic entries. In contrast, late priming effects (i.e., after 500 ms) are characterized by selection of highly related semantic information and inhibition of unrelated word pairs in the left hemisphere. Selection and inhibition effects are assumed to reflect controlled processes whereby the semantic system is strategically scanned. Given that controlled processing is mediated by conscious awareness of semantic information, selective and inhibitory processes likely contribute to explicit lexical access. Thus, evidence for automatic and controlled processing in the left hemisphere suggests that normal word recognition involves lexical access at both implicit and explicit levels. In addition, the time course of these effects implies that word recognition at the semantic level is a two-stage process mediated first by early implicit lexical access, then lexical access at the explicit level. Controlled processing at later temporal intervals suggests that explicit access is mediated by selection of highly related semantic information and inhibition of less relevant candidates.

The results from divided visual field research with the normal population suggest several hypotheses regarding semantic processing in the left hemisphere. Specifically, if word recognition involves both implicit and explicit access, then there should be evidence that performance that hinges on these processes dissociates at the task level. Preliminary support for dissociation in performance based on task demands is provided by priming studies with left hemisphere patients. Specifically, patients with left hemisphere lesions showed automatic activation for a broad range of semantic information, but diminished ability to select among semantically related lexical competitors and use contextual

information to inhibit inappropriate meanings over time (e.g., Henik et al., 1993; Hagoort, 1997; Milberg & Blumstein, 1981; Bushell, 1996; Blaxton & Bookheimer, 1993; Copland et al., 2002). These results suggest that left hemisphere patients have spared implicit access to semantic information, but impaired lexical access at the explicit level due to disrupted selective and inhibitory processes.

If selection and inhibition result in lexical access at the explicit level, and it is this mechanism that is compromised in left hemisphere brain damage, then patients with focal lesions in the left hemisphere should show deficits only on tasks that require explicit lexical access. Research with patients demonstrating focal left hemisphere lesions lends preliminary support to this hypothesis. For example, Milberg and Blumstein showed that aphasic patients with left hemisphere damage were significantly impaired on semantic judgement tasks (Milberg & Blumstein, 1981; Blumstein, Milberg, & Shrier, 1982). Given that semantic judgement tasks require comparison of meanings to determine whether words are related, this task is mediated by conscious awareness of semantic information. Thus, deficient performance on the semantic judgment task for left hemisphere patients clearly reflects impaired explicit access. Considered within the context of priming effects for a broad range of semantic information at early temporal intervals (e.g., Henik et al., 1993; Hagoort, 1997; Milberg & Blumstein, 1981; Bushell, 1996; Blaxton & Bookheimer, 1993; Copland et al., 2002), which suggests intact lexical access at the implicit level, these results imply dissociation between implicit and explicit lexical access in patients with left hemisphere damage.

It is interesting to note that the results from divided visual field studies with neurologically intact and brain damaged patients are consistent with the FIT as an

explanation for deep dyslexia. Specifically, hemispheric studies support the distinction between implicit and explicit access, and suggest that left hemisphere damage results in impaired explicit access due to slowed or reduced inhibitory connections. However, whereas the findings from divided visual field studies suggest that damage is at the level of semantics, FIT proposes that the damage is at the level of the phonological output lexicon. The following sections review evidence for the distinction between implicit and explicit access, as well as data that implicate failure of inhibition as the mechanism of impairment in deep dyslexia. In addition, the methods section presents a series of experiments designed to elucidate the location of damage (i.e., semantic system versus phonological output lexicon).

THE DISTINCTION BETWEEN IMPLICIT AND EXPLICIT ACCESS IN DEEP DYSLEXIA

Intact Implicit Access in Deep Dyslexia

If damage to the left hemisphere selectively impairs explicit access (but spares implicit processing), and deep dyslexia results from left hemisphere damage, then there should be evidence that deep dyslexic performance dissociates based on implicit and explicit task demands. More specifically, if automatic spread of activation results in implicit lexical access and this process is intact in deep dyslexia, then there should be evidence for normal semantic priming effects. Because the normal effect for semantic context is facilitation (see Schmidt, 1976; Klein, Briand, Smith & Smith-Lamothe, 1988; Brodeur & Lupker, 1994; Balota & Paul, 1996; also see Damian, Vigliocco, & Levelt, 2001 for naming), deep dyslexics should show semantic priming in lexical decision tasks for words blocked into semantically related categories relative to random conditions: As each word is presented in succession, the corresponding entry in the semantic system is activated and this activation spreads to semantically related items. As more words are presented within the semantic category, more semantically related candidates are activated through the spread of activation. Boosting the activation level of semantically related items prior to their presentation should facilitate responses to these items because lexical status is easier to determine. In addition, because more semantically related items are activated for each presentation within a given semantic category, faster and more accurate response times are expected to accrue for items presented in the second half of each semantic category relative to items in the first half.

Colangelo and Buchanan (in press) tested these predictions using a lexical decision task with a deep dyslexic patient (JO) who has participated extensively in our laboratory for other experiments (see details regarding her performance on page 30). The stimulus set consisted of 300 common words blocked according to 20 semantic categories (i.e., fifteen semantically related words comprised each of the 20 categories). The categories were selected based on list stimuli used by Roediger and McDermott (1995). These lists were initially constructed by obtaining the first 15 semantic associates listed in Russel and Jenkin's (1954) word association norms. For example, one list of associates (to the word *bread*) included *butter, food, eat, sandwich, rye, jam, milk, flour, jelly, dough, crust, slice, wine loaf, and toast*. In the blocked condition, the words were presented in semantically related categories interleaved with 300 nonwords. In the unblocked condition, the same words were presented in random order with the nonword stimuli. Conditions were counterbalanced and temporally separated such that the blocked (*1st blocked and 2nd blocked*) and random (*1st random and 2nd random*) conditions were presented twice, each presentation on different days.

The results of lexical decision with JO revealed more semantic priming for words in the second half of semantic categories relative to items in the first half of categories. Because this finding is consistent with the effects for semantic context observed in neurologically intact participants (see Schmidt, 1976; Klein et al., 1988; Brodeur & Lupker, 1994; Balota & Paul, 1996; also see Damian et al., 2001 for naming), these results suggest that implicit processing of semantic information is intact in deep dyslexia.

Impaired Explicit Access in Deep Dyslexia

To support the distinction between implicit and explicit lexical access in deep dyslexia there must be evidence for preserved implicit processing, as described above, in conjunction with evidence of impaired performance on explicit tasks. In other words, given the postulation that selective and inhibitory processes result in explicit lexical access in the semantic system, and that damage to the left hemisphere disrupts the mechanisms of meaning inhibition, there should be evidence for failed inhibition under conditions that require explicit processing in deep dyslexia. Because successful aloud reading requires explicit lexical access, manipulating spread of activation by presenting words blocked into semantically related categories should impact reading performance in a predicted direction: As each word is presented in succession, the corresponding entry in the semantic system is activated. Through the spread of activation, semantically related entries are co-activated. As more words are presented within the semantic category, more semantically related candidates are activated. In the context of impaired selective and inhibitory processes, the number of options for selection continues to increase with each semantically related presentation, thereby increasing the probability of semantic errors relative to conditions that present words in random order.

To test these predictions, Colangelo, Buchanan, and Westbury (2004) presented the identical 300 words from the earlier cited lexical decision task as targets in a naming task. In the blocked condition, the words were presented together in the 20 semantically related categories. JO was asked to read each word aloud and her responses were recorded verbatim. Two weeks later, JO was asked to read the same 300 words presented in random order. Qualitative analysis was performed on her aloud responses to determine

the number and type of reading errors (e.g., semantic, phonological, morphological errors, as well as circumlocutions and no responses).

As first responses, JO made 47 semantic errors to targets in the blocked condition. In contrast, she produced only 7 semantic errors in response to the same words presented in random order (refer to Table 1 for examples). These results provide quantitative evidence that supports failed inhibition as the mechanism for impaired explicit access. However, FIT predicts that impaired selective and inhibitory processes will also impact the overall *pattern* of errors. Specifically, given failed inhibition, the number of candidates available for selection continues to increase with each semantically related presentation. As such, errors should accrue as a function of position within semantic categories. Consistent with this prediction, Colangelo et al. (2004) found a significant semantic interference effect when responses to words in the first half were compared with responses to words in the second half of the lists (e.g., *butter, food, eat, sandwich, rye, jam*, and *milk* were in the first half of the category, whereas *jelly, dough, crust, slice, wine, loaf*, and *toast* were in the second half of the category): JO produced more errors in the second half of each list compared with the first half. In fact, the proportion of overall errors increased from 47% (66/140) of responses to the first half of words across lists to 59% (83/140) of responses for the second half of the words. In contrast, there was no difference in number of errors in the first half and second half of the semantic category for matched words in the random condition.

Cumulatively, the number and pattern of errors in the blocked relative to random aloud reading conditions not only suggests a role for spread of activation in mediating the number of candidates available for selection, but also implicates failure of inhibition as

the mechanism for impaired explicit access. That impaired explicit access departs from the facilitation in naming performance seen in the normal population for semantic context provides additional support for the FIT as an explanation for deep dyslexia (see Damian et al., 2001 for naming in intact participants).

TABLE 1. Reading Responses to Words in Blocked and Random Conditions

Target	Response to Target in Blocked	Response to Target in Random
butter		
food		
eat		eating
sandwich		
rye		
jam		
milk		
flour	sugar, flour	
jelly	jam, jelly	
dough		
crust	crumbs	
slice	cheese	
wine		
loaf	loaves	
toast		

A SYSTEMATIC TEST OF THE FAILURE OF INHIBITION THEORY

As stated previously, the semantic blocking studies reviewed above were completed with JO, a deep dyslexic patient first identified in 1999. Since that time, she has participated extensively in investigations conducted in our laboratory and is the focus of the current research program. The studies presented in this dissertation were conducted serially over the past two years, each several months apart. At present, JO is 53-years old. She has 14 years of formal education, two of which were at the postsecondary level. She was first tested 20 years after the removal of a tumour in the left temporal-parietal region, which the treatment of and later complications left JO with right side paralysis and profound language disturbances. Unfortunately, neuroimaging results are currently not available for review.

During the screening phase, JO demonstrated non-fluent aphasia characterized by very slow, halting speech production. Her utterances were of significantly reduced length and agrammatic in nature (i.e., typically comprised of single word responses). Given the extent of her production language difficulties, which included very slow reading rate (i.e., reading of single word responses at a rate of approximately 16 targets per hour), and in respect of her time, comprehensive standardized neuropsychological testing was not completed. Although not formally tested, she demonstrated good auditory comprehension for conversational speech and she was able to understand complex task instructions without difficulty. During repetition of 300 single and multi-syllabic words, she made 33 errors, none of which were semantic responses. With respect to naming, she produced 134 errors to 242 stimuli pictures, with 73 of her responses being semantic errors. During this initial screening phase, JO was also asked to read aloud 300 single-

syllable words and 108 nonwords. Of the 300 common English words, JO correctly read only 126 words and made 46 frank semantic errors (see Table 2 for summary of error type reported in Buchanan et al., 2003). Regarding the 108 nonwords, she was initially unable to read aloud a single letter string. As such, her pattern of errors on these tasks is consistent with the profile of deep dyslexia. The following series of experiments constitute a systematic examination of issues raised in previous work and attempt to refine the description of deep dyslexia.

Table 2. Example of Errors JO Made During Screening

Error type	Target	Response	Error proportion
Phonological	STYLE	SMILE	3/174
Orthographic	TRIED	TIRED	3/174
Phonological/orthographic	PLOT	POT	16/174
Morphological	SHOWN	SHOWING	10/174
Semantic	DEBT	MONEY	46/174
Other	NEAR	STAIR	16/174
No attempt*			80/174

Note. "*No attempt" responses are items that JO indicated she could not read either by saying "no" or "I don't know."

Distinction between Explicit and Implicit Access at the Level of the Representation

By manipulating semantic context, the blocking paradigm provided clear support for the distinction between implicit and explicit access at the task level. However, in order to demonstrate that this distinction also exists at the level of the representation, performance must be shown to dissociate based on explicit and implicit task demands for word level semantic variables (e.g., number of semantic neighbourhoods). Important to the test of this distinction is the fact that some orthographic representations correspond to multiple meanings (e.g., BANK) and thus are semantically ambiguous (i.e., BANK is

associated with MONEY and RIVER meanings). Given multiple representations in the semantic system, these words are linked to several distinct semantic neighbourhoods. In contrast, unambiguous words (e.g., FOOD) correspond with only one concept and therefore are consistently associated with one semantic neighbourhood. Based on the assumption that ambiguous and unambiguous words are associated with a different number of semantic neighbourhoods, the FIT predicts that these words should differ with respect to explicit lexical access. Specifically, deep dyslexics are expected to produce more semantic errors to ambiguous relative to unambiguous words during aloud reading because these items are associated with several distinct semantic neighbourhoods and a correspondingly large number of activated candidates competing for selection in the context of failure of inhibition.

In contrast, given that the effects of failed inhibition are only expected in conditions that require explicit selection, performance on tasks that require implicit processing should parallel that observed in the normal population (e.g., lexical decision). Given the normal advantage for ambiguous relative to unambiguous words based on implicit task demands (e.g., Borowsky & Masson, 1996), the FIT predicts that deep dyslexics show facilitation for ambiguous compared with unambiguous words in lexical decision. Evidence for dissociation in performance based on explicit and implicit task demands at the word level would strongly support the distinction between explicit and implicit access. Moreover, this finding would indicate failure of inhibition as the mechanism for impaired explicit access.

METHODS

Experiment 1a and 1b: Distinction between Explicit and Implicit Access at the Word Level

Experiment 1a: Semantic Ambiguity Reading

The stimuli administered to JO were identical to the stimulus set originally used by Borowsky and Masson (1996). This stimulus set consisted of 64 matched pairs of ambiguous and unambiguous words that were controlled for initial phoneme, word frequency, and word length. The words were also similar with respect to spelling-to-sound regularity, orthographic familiarity, and number of higher frequency neighbours. Each word was individually printed in 16-point font on 3X5 index cards. Ambiguous and unambiguous words were presented in random order. JO was asked to read each word aloud. The task was participant paced and no time limits were imposed.

Experiment 1a: Results and Discussion

According to the FIT, ambiguous words should result in more semantic errors than unambiguous words. The current investigation revealed support for this prediction (See Table 3 for error proportions): As first responses, JO produced equivalent number of total errors in ambiguous (39 errors) and unambiguous (43 errors) conditions, $\chi^2(1, N = 128) = 0.54, p = 0.46$. In contrast, the proportion of semantic compared with total errors was greater for ambiguous (56.4% of total errors) relative to unambiguous (32.6% of total errors) words, $\chi^2(1, N = 82) = 4.72, p = 0.03$. The increase in semantic errors for ambiguous compared with unambiguous words implies intact ability to activate semantically related candidates and suggests sensitivity to subtle semantic distinctions at the word level. As such, JO's performance cannot easily be attributed to a failure to

access entries in the semantic system. Instead, increased number of semantic errors in response to ambiguous relative to unambiguous words indicates a deficit in the ability to address semantically related entries: Given that ambiguous words are associated with multiple representations in the semantic system, more semantic neighbourhoods are activated and a correspondingly large number of candidates are available for potential selection in the context of failed inhibition relative to unambiguous words.

Analysis of the pattern of responses in ambiguous compared with unambiguous conditions provides additional support for the FIT: JO made 14 semantic errors as first responses to unambiguous words (21.9% of total responses), which is entirely consistent with her semantic error rate on earlier screening tasks. In addition to semantically related responses, JO produced phonological, morphological, and orthographical errors, as well as short circumlocutions and no responses. Of note, the number of nonsemantic errors in response to unambiguous words (45.3% of total responses) was directly proportional to the number of nonsemantic errors produced in most reading tasks we have conducted with her (approximately 46.3% of total responses). Thus, the pattern of errors in the unambiguous condition is consistent with her typical performance and with the classic deep dyslexia profile. In contrast, the pattern of errors for ambiguous words was numerically and qualitatively identical to predictions based on the FIT: JO produced 22 semantic errors (34.4% of total responses) in response to ambiguous words, proportionately greater semantic errors than that observed for the unambiguous condition (34.4% versus 21.9%, Fisher's test $p = 0.08$). Importantly, this result occurred in the context of fewer nonsemantic errors for ambiguous (26.6% of total responses) compared with unambiguous (45.3% of total responses) words, $\chi^2(1, N = 128) = 4.89, p = 0.03$,

which suggests a shift in the distribution of error type from nonsemantic to semantic responses and indicates deviation from her typical performance profile.

Table 3. Proportion of Errors for Ambiguous and Unambiguous Words

Error type	Ambiguous Error	Unambiguous Error
Orthographic	2/64	2/64
Phonological/orthographic	4/64	5/64
Morphological	2/64	3/64
Semantic	22/64	14/64
Other	2/64	6/64
No attempt*	7/64	13/64
Total Errors	39/64	43/64

Note. "*No attempt" responses are items that JO indicated she could not read either by saying "no" or "I don't know."

The increase in semantic errors for ambiguous relative to unambiguous words during aloud reading is consistent with failure of inhibition as an explanation for reading errors in deep dyslexia. However, the effects of failed inhibition are only expected in conditions with an explicit selection requirement. In contrast, implicit processing is assumed to be intact in deep dyslexia. Support for intact implicit processing requires that deep dyslexic performance parallel normal performance on tests of implicit access. Evidence for an ambiguity advantage in lexical decision in the context of increased semantic errors for these same words during reading would support the distinction between explicit and implicit processing in deep dyslexia at the word level.

Experiment 1b: Semantic Ambiguity Lexical Decision

The stimulus set for lexical decision consisted of the same stimuli presented earlier in the reading task interleaved with nonwords. Each target was presented individually on a computer screen using DirectRT software (Jarvis, 2002). The target

remained on the screen until a lexical decision was registered. To indicate her responses, JO was asked to press a key designated for word or nonword responses. JO was instructed to respond quickly without compromising accuracy. RTs were measured in milliseconds from the onset of the letter string to key press.

Experiment 1b: Results and Discussion

Analysis of mean reaction time revealed slower responses to nonwords ($M = 1757$, $SD = 1188$) compared with words ($M = 1325$, $SD = 772$), $t(241) = -3.32$, $p = 0.001$. There was no difference between ambiguous ($M = 1327$ ms, $SD = 910$ ms) and unambiguous conditions ($M = 1323$ ms, $SD = 591$ ms) in lexical decision, $t(114) = 0.03$, $p = 0.98$. However, responses to ambiguous word trials yielded higher accuracy rates than responses to unambiguous word trials, (95.3% versus 85.9%, Fisher's test $p = 0.06$). This result parallels facilitation in lexical decision typically observed in the normal population for ambiguous relative to unambiguous words (e.g., Borowsky & Masson, 1996). Given consideration for the small sample size used in this experiment, the higher accuracy rate for ambiguous compared with unambiguous words suggests an advantage for these words in the context of implicit task demands.

Impaired reading aloud performance provides support for impaired semantic access at the explicit level (as suggested by the divided visual field studies). However, given that aloud reading requires both explicit access to a particular representation in the semantic system, as well as access to the phonological output lexicon in order to support an oral response, the effects of semantics and phonology on aloud reading performance are confounded. In order to *clearly* demonstrate that explicit access to *semantic information* is impaired in deep dyslexia and *isolate damage to the semantic system*,

performance must be shown to be impaired given task demands for explicit semantic access *without* production (i.e., impaired performance on a task mediated by explicit access that does not require an oral response).

Experiment 2a and 2b: Explicit Decision Tasks without Production

In the current investigation, JO was asked to read 45 lists, each comprised of words that converged in meaning on one nonpresented word (see Appendix 2 for stimuli). Each list was followed by a forced choice trial that included the converged word for that list and a semantically related word. The lists varied in difficulty as to the ease with which the most associated word was identifiable. All 45 lists used in this experiment were balanced such that half the lists converged on the first option and half the lists converged on the second option in the forced choice trials.

Experiment 2a: Unambiguous Semantic Decisions

Twenty of the lists were comprised of 15 words (e.g., *college, book, desk, learn, gym, student, pen, teacher, class, education, library, blackboard, friend, grade, and, chalk*) that *clearly* converged in meaning on one nonpresented item. The forced choice trial for each of these lists included the nonpresented word (e.g., *school*) and a second word (e.g., *yard*) that was related to the nonpresented word, but was not strongly associated with any other word on that list. JO was instructed to read each list silently and choose the option that was most associated with all other words on the list.

Experiment 2a: Results and Discussion

For the 20 lists comprised of 15 words that clearly converged in meaning on one nonpresented item, JO correctly selected the nonpresented item associated with all other words on the list 100% of the time (e.g., selected *school* instead of *yard*). This result

indicates that JO was able to reliably access and discriminate unambiguous semantic relationships at an explicit level without the requirement of production (contrary to divided visual field studies but consistent with FIT). However, before concluding that explicit access is intact in deep dyslexia, it is necessary to examine her ability to perform more difficult semantic decisions.

Experiment 2b: Difficult Semantic Decisions

The remaining 25 lists consisted of words selected based on list stimuli used by Roediger, Watson, McDermot, and Gallo (2001). These lists were initially constructed by obtaining the first 15 associates (e.g. *moth, insect, wing, bird, fly, yellow, net, flower, bug, cocoon, summer, color, bee, stomach, and worm*) to a cue (e.g., *butterfly*) catalogued in word association norms. The items on each list decreased in strength of association to the cue: On each list, the first item (e.g., *moth*) was the strongest associate and the last item was the weakest associate (e.g., *worm*) of the cue (e.g., *butterfly*). Each list presented in this experiment was comprised of the first 14 associates to the critical nonpresented cue. The forced choice trials included the critical nonpresented cue (e.g., *butterfly*) and the 15th associate to that cue (e.g., *worm*). Given that the 14 list words were all associates to the critical nonpresented cue, all the words on each list were associatively related to the critical nonpresented cue for that list. In contrast, the second option in the forced choice trial (15th associate) was an associate of only the critical nonpresented cue. Thus, the nonpresented critical cue was considered to be the correct option for each list (i.e., the forced choice item most strongly associated to all other words on each list). Importantly, given that performance on the forced choice trial is mediated by access to implicit

information regarding associative relationships, it is assumed that this task requires an intact associative network in the semantic system.

To further increase task difficulty, the first and most strongly associated item (e.g., *moth*) to the critical nonpresented cue (e.g., *butterfly*) was deleted in order to decrease the identifiability of the critical nonpresented cue. Of the 25 word association lists, JO was instructed to read five lists aloud before selecting the option in the forced choice trial that was most associated with all other words for each list. This criterion allowed a sample of her reading performance in the context of production, thus ensuring that the words included in these lists did not produce a ceiling effect (i.e., errorless performance, irrespective of the manipulation). She read the remaining 20 lists silently prior to completing the forced choice trial.

Normative Sample Methods and Results

These 25 word association lists were also completed by 21 neurologically intact participants, who served as the normative sample for this study. Participants were volunteers recruited from the community who ranged in age from 20 to 51 years and in educational level from 12 to 17 years. Participants were not offered compensation for completing the task. Instructions were as follows: "Please read each list, then circle one of the two options (A or B) that is most associated with all other words on that list (there are no right or wrong answers)." With respect to the 25-word association lists, the critical nonpresented cue was selected as the option most strongly associated with all other items on each list with an average accuracy of 86% ($M = 22.50$, $S.D. = 2.44$). Accuracy ranged from 64% (i.e., 16/25) to 100% (i.e., 25/25). These findings indicate the utility of this task for evaluating explicit semantic access to implicit associative relationships.

Experiment 2b: Results and Discussion

The FIT assumes that reading errors in deep dyslexia result from slowed or reduced inhibitory connections. If damage is isolated to the semantic system, then there should be evidence for impaired explicit semantic access to implicit information regarding associative relationships when production is not required for task performance. Contrary to this expectation, JO's performance was within normal limits: She selected the critical nonpresented cue as the option most strongly associated with all other items on each list with an accuracy of 76% (19/25), which was within the range observed in the normative sample. Given that her performance on this task paralleled performance in the neurologically intact sample, these results indicate that JO was able to access implicit associative information and discriminate fine-grained semantic relationships at the explicit level when performance was not mediated by production.

Intact performance on the forced choice explicit trials occurred in the context of impaired performance given similar task demands with the additional requirement for production (see Table 4): JO was asked to read five of the 25 word-association lists aloud before selecting the option in the forced choice trial that was most associated with all other words for each list. Her reading performance across these lists was entirely consistent with the large proportion of semantic errors she produced on the earlier semantic blocking reading task (Colangelo et al., 2004 see Table 5) and with the classic deep dyslexia profile.

Table 4. Proportion of Errors for Semantic Decision Reading Lists

Error type	Error proportion
Orthographic	2/65
Phonological/orthographic	3/65
Morphological	1/65
Semantic	14/65
Other	6/65
No attempt*	9/65
Total Errors	35/65

Note. "*No attempt" responses are items that JO indicated she could not read either by saying "no" or "I don't know."

Table 5. Comparison of Error Rate for Words Read in Colangelo et al., 2004 and the Current Experiment

	Blocked condition Colangelo et al.	Random Condition Colangelo et al.	Reading list words current experiment
Semantic errors	47	8	14
Total errors	158	128	35
Total # items	300	300	65

Normal performance on semantic decision tasks in the context of impaired performance with the additional requirement of production strongly suggests that the damage to the language system in deep dyslexia is not at the level of the semantics (as was implied by divided visual field research). Instead, these results suggest that damage is at the next level of representation: The phonological output lexicon.

DEEP DYSLEXIA AND THE PHONOLOGICAL OUTPUT LEXICON

Buchanan et al. (2003) proposed that the phonological deficits observed in deep dyslexia reflect production errors due to compromised explicit access. According to this perspective, compromised explicit access results from selection impairments in the phonological output lexicon due to a failure of inhibition. According to the FIT, an inability to name nonwords in deep dyslexia results because nonwords provide no semantic lexical activation to boost activation levels of phonological representations.

Implicit and Explicit Access: Phonology

If impaired nonword reading in deep dyslexia results from failure to inhibit co-activation in the phonological output lexicon, then there should be evidence for intact ability to process phonology given implicit task demands because inhibition failure is not expected to affect the availability of lexical entries, only explicit access and production. Indeed, several findings support the proposed dissociation between implicit and explicit access to phonological representations and challenge conceptualizations of deep dyslexia that hinge upon a complete inability to process phonology. For example, Katz and Lanzoni (1992) reported a deep dyslexic patient who showed a normal advantage for rhyming words (e.g., bribe-tribe) relative to trials with nonrhyming stimuli (e.g., couch-touch) in a lexical decision task. Hildebrandt and Sokol (1993) similarly established that implicit phonological knowledge contributes to word recognition performance in deep dyslexia: Their patient evidenced a normal regularity effect for low-frequency words such that he made faster and more accurate lexical decisions to words with typical spelling-sound correspondences (e.g., gave, save) than to words with atypical spelling sound correspondences (e.g., have). These investigations indicate that, although deep dyslexic

patients show impaired ability to assemble phonology explicitly (i.e., read aloud nonwords), these patients are influenced by word phonology at an implicit level.

Buchanan, Hildebrandt, and MacKinnon (1994, 1996) demonstrated that some patients with deep dyslexia also show preserved implicit phonological processing for nonwords. In a series of experiments with three deep dyslexic patients, they found a normal pseudohomophone effect: Reaction times to reject nonwords that sound like words (e.g., *taybul*) were slower than responses to orthographic control nonwords (e.g., *tarbul*). In addition, these patients showed normal semantic priming with pseudohomophone primes in lexical decision (e.g., faster reaction times to the word *chair* when preceded by the prime *taybul* than after orthographic control nonwords e.g., *tarbul*). Cumulatively, these results indicate that deep dyslexics are sensitive to phonological information for words and nonwords despite impaired explicit access. Importantly, implicit phonological analysis resulted in normal effects, which suggests intact phonological representations and normal patterns of activation. In addition, the findings for intact implicit phonological processing of nonwords indicate that the primary locus of the deficit in deep dyslexia is not sublexical (i.e., deep dyslexic patients have preserved assembled phonology). Instead, these findings suggest that poor nonword reading results from impaired explicit access to assembled representations in the phonological output lexicon.

According to the FIT, impaired explicit access to assembled phonology results from grossly impaired ability to discriminate activation levels of phonological neighbours because regular nonwords lack any lexical representation to assist in selecting appropriate candidates in the phonological output lexicon. However, the assembled phonology of

pseudohomophone nonwords (PH) is linked to semantic representations through feedback connections from the phonological output lexicon to the semantic system. As such, there should be evidence for better reading performance with PHs relative to regular nonwords: Semantic activation associated with PHs boosts the activation levels of candidates with consistent phonology (real word phonological equivalents, PE), thereby substantially constraining the number of potential options available for selection relative to regular nonwords. Consistent with this prediction, Buchanan, Kiss, and Burgess (2000) showed better reading by a deep dyslexic patient (SD) for PHs than orthographically controlled nonwords. Importantly, Buchanan et al. (2003) replicated this result with another deep dyslexic, despite the fact that this patient showed profoundly impaired reading for regular nonwords (i.e., she failed to correctly read a single regular nonword). Together, these findings provide evidence that deep dyslexics are capable of processing subword phonology on an explicit level when additional semantic activation is available. However, in order to demonstrate that semantic activation is sufficient to support explicit access to consistent assembled phonology, it is necessary to demonstrate that deep dyslexics not only show better reading of PHs relative to regular nonwords, but also show reading performance for PHs that parallels that of their real word PEs.

Experiment 3: Pseudohomophone Reading

The current investigation presents the results of a post hoc analysis of reading performance for PH nonwords and their real word PE. For each type of stimuli (i.e., PHs versus real word PE), a subset of 65 words was selected from a larger 156-item data set based on the availability of matched pairs of PHs (e.g., *rawky*) and real word PEs (e.g., *rocky*). These words were originally presented as control stimuli in two other pilot studies

conducted six months apart. In each of these studies, JO was simply asked to read each letter string aloud (see Appendix 2 for stimulus set). Each word was individually printed in 16-point font on 3X5 index cards. The task was participant paced and no time limits were imposed.

Experiment 3: Results and Discussion

This post hoc analysis revealed support for the postulation that semantic activation alone is sufficient to support explicit access to consistent assembled phonology: As first responses, JO correctly read a similar number of stimuli in PH (11) and real word PE (19) conditions, $\chi^2(1, N = 130) = 2.77, p = 0.10$, which is in contrast to her initial inability to decode any nonword stimuli. Analysis of the *pattern* of responses in PH condition provides additional support for the prediction that deep dyslexics show reading performance for PHs that parallels that of their real word PEs: JO made 17 semantic errors as first responses to PHs, which is entirely consistent with her semantic error rate for real word PEs (18 semantic errors), $\chi^2(1, N = 130) = 0.04, p = 0.84$. In addition to semantically related responses to PHs, JO produced phonological, morphological, and orthographical errors, as well as short circumlocutions and no responses. Thus, the pattern of errors in the PH condition is consistent with her typical performance and with the classic deep dyslexia profile (see Table 6 for proportion of errors).

Table 6. Proportion of Errors for Matched PH and PE

Error type	PH	PE
Orthographic	5/64	2/64
Phonological/orthographic	6/64	6/64
Morphological	1/64	3/64
Semantic	17/64	18/64
Other	2/64	5/64
No attempt*	22/64	11/64
Total Errors	53/64	45/64

Note. "*No attempt" responses are items that JO indicated she could not read either by saying "no" or "I don't know."

It is important to note that JO's good PH reading cannot simply be attributed to her mistaking PH orthography for real words: In a separate analysis, JO was asked to name 14 semantically related PHs (i.e., *truk, automobil, vehicel, jeep, raice, weel, speed, stear, braik, pedel, geer, streat, dashbord, and traval*). As first responses, she correctly read only two PHs and produced semantic errors to four others. However, when later asked to identify the correct spelling for each letter string, none was accepted as real word orthography (see Table 7 for a comparison of her reading and spelling responses). In fact, JO was able to accurately transcribe the spellings for eight PHs (i.e., *truck, vehicle, jeep, race, speed, steer, gear, and travel*), two of which resulted in "I don't know" responses during the naming task (i.e., *raice* and *geer*). Moreover, she produced orthographically similar written responses to two additional PHs (i.e., *braik* → *brain* and *streat* → *stream*) and a word response to a third (*pedel* → *delay*). Although JO was unable to produce word spellings for the remaining PHs, she was able to indicate where the incorrect orthography was in the letter string (e.g., she pointed to the last three letters for *automobel*).

Table 7. Responses to PH

Stimulus	Reading Responses	Written Spelling Responses
truk	truck	truck
automobel	car	automatir, automobile
vehicel	car	vehicle
jeap	jeep	jeep
raice	no attempt	race
weel	wool	weal, wael
spead	spread	speed
stear	deer	steer
braik	eyes	brain
pedel	bicycle	pedle, ped, delay
geer	no attempt	gear
streat	no attempt	stream, treats
traval	fly	travel
dashbord	dash	no attempt

*Note: Multiple attempts were made to automobel, weel, pedel, and streat.

None were accepted as correct

Together, these results strongly indicate that JO is capable of assembling subword phonology and accessing nonword representations at an explicit level. The fact that the PH stimuli are associated with semantic representations suggests the role of semantic activation in supporting this explicit access: The semantic information available via feedback connections from pseudohomophone assembled phonology to the semantic system boosts the activation levels of candidates with consistent phonology, thereby substantially constraining the number of potential options available for selection relative to regular nonwords.

Despite similar performance in the PH and real word PE conditions, which implies intact explicit access to assembled phonology with additional semantic information, naming performance was still grossly impaired: Semantic information was

only sufficient to resolve the lexical status of the letter string for approximately 17% of the PH stimuli (and 30% for real word PEs). However, aloud reading tasks necessarily confound explicit access with processes associated with production. Thus, in order to more clearly demonstrate that semantic activation is sufficient for explicit access to assembled phonology, intact performance must be shown given task demands for explicit phonological access without production. Moreover, if deep dyslexics are able to access assembled phonology on an explicit level, and this explicit access is mediated by semantic activation, then there should be evidence for intact discrimination between real word PEs of previously read PHs and other semantically related words.

Experiment 4: Forced Choice Pseudohomophone Lists

The stimulus set consisted of 10 lists comprised of 14 PHs (e.g., *taybul*, *leggs*, *seet*, *reclinur*, *kushion*, *stule*, *siting*, *rockur*, *kitchin*, *flor*, *lapp*, *hed*, *offis*, and *mann*).² The real word PEs for the PHs on each list converged in meaning on one nonpresented word (e.g., *chair*). Each list was followed by a forced choice trial that included the converged word for that list (e.g., *chair*) and a semantically related word that was not strongly associated to all the real word PEs for that list (e.g., *bench*). JO was asked to read each list silently and then select the option that is most strongly associated with **all** the real word PEs for that list (e.g., *chair*). Immediately following the forced choice trial for each list, each real word PE from that list was included along with semantically related words in a yes/no recognition paradigm (e.g., *rest*, *rocker*, *table*, *couch*, *back*, *head*, *office*, *legs*, *seat*, *butt*, *relax*, *maple*, *bed*, *high*, *man*, *sitting*, *recliner*, *desk*, *kitchen*, *four*, *lap*, *sofa*, *wood*, *floor*, *cushion*, *stool*, and *swivel*). Each word was individually printed in 16-point font on

² The lists used in this experiment were based on the false memory stimuli initially constructed by Roediger, Watson, McDermot, and Gallo (2001). List words that could not appropriately be converted to pseudohomophones were replaced with other semantically related pseudohomophones.

3X5 index cards. JO was simply asked to indicate whether each written word sounded like any of the letter strings presented on the previous list by providing a yes or no response (see Appendix 2 for stimulus set).

Experiment 4: Results and Discussion

For the 10 lists comprised of 14 pseudohomophones that converged in meaning on one nonpresented item, JO correctly selected the nonpresented item associated with all PHs on the list 100% of the time (e.g., selected chair instead of bench). This finding strongly suggests that the semantic activation available from the PHs was sufficient to support explicit access to assembled phonology: The task requires processing of semantic information associated with each PHs on the list in order to reliably discriminate fine-grained semantic relationships in the forced choice trials (i.e., determining which of the two options is most strongly related to all list pseudohomophones). As such, good performance on this task necessarily requires intact ability to assemble and achieve explicit access to PH representations. Performance on the yes/no recognition trial also supported this conclusion: Of the 275 total trials presented in the recognition paradigm following each forced choice trial, JO accurately identified 214 words (78%). With respect to the 139 real word PEs of previously presented PHs included in the recognition paradigm, JO correctly recognized 93 targets (67%). She falsely recognized only 15 of 136 semantically related foils (11%).

The results of Experiment 4 demonstrate that JO was able to reliably access phonological information with additional semantic information and discriminate fine-grained semantic relationships at an explicit level. However, without the requirement for production it is not clear how the pattern of errors generated during the PH reading task

(i.e., naming the PHs on each list) would have affected subsequent ability to explicitly access and distinguish semantic relationships (i.e., the forced-choice and recognition trials), particularly with respect to the influence of producing semantic errors during reading: In the context of failed inhibition, the additional spread of activation in the semantic system related to the generation of semantic (and other) errors may have resulted in reduced ability to correctly identify which option in the forced-choice trial was most related to all other PHs on the list, as well as increased error rate during the recognition trials.

Experiment 5: Pseudohomophone Naming and Forced Choice Pseudohomophone Lists

The methods were generally identical to Experiment 5, except for the requirement to read list PHs aloud: The stimulus set consisted of 10 lists comprised of 14 PHs (e.g., *breeth, snif, heer, whif, reak, flowurs, awfull, sence, sneez, skunc, baik, oder, gud, and nostrel*). The real word PEs for the PHs on each list converged in meaning on one nonpresented word (e.g., *smell*). Each list was followed by a forced choice trial that included the converged word for that list (e.g., *smell*) and a semantically related word that was not strongly associated to all the real word PEs for that list (e.g., *rose*). JO was asked to read each list aloud and then select the option that is most strongly associated with **all** the real word PEs for that list (e.g., *smell*). Her responses during the reading task were recorded. Immediately following the forced choice trial for each list, each real word PE from that list was included along with semantically related words in a yes/no recognition paradigm (e.g., *bad, breath, sense, sneeze, good, nose, stench, fragrance, flowers, awful, skunk, bake, sniff, aroma, see, nostril, odour, hear, reek, whiff, perfume, scent, salts,*

taste, five). Each word was individually printed in 16-point font on 3X5 index cards. JO was simply asked to indicate whether each written word sounded like any of the letter strings presented on the previous list by providing a yes or no response (see Appendix 2 for stimulus set).

Experiment 5: Results and Discussion

With respect to first responses in the naming task, JO correctly identified 35 PHs (25% of total reading responses) and made 30 semantic errors (21% of total reading responses). In addition, she produced phonological, morphological, and orthographical errors, as well as short circumlocutions and no responses. This pattern of errors is consistent with her performance during the previous PH reading task (Experiment 3) and with the classic deep dyslexia profile (see Table 8).

Table 8. Proportion of Errors for Read PH Lists

Error type	Target	Response	Error proportion
Orthographic	WEEL	WOOL	10/140
Phonological/orthographic	SCREEN	SCREAM	8/140
Morphological	FLOWURS	FLOWER	9/140
Semantic	KAMP	SUMMER	30/140
Other	TAWL	CAB	17/140
No attempt*			31/140

Note. "*No attempt" responses are items that JO indicated she could not read either by saying "no" or "I don't know."

The results of forced-choice and recognition trials replicated the findings of Experiment 4: For the 10 lists comprised of 14 pseudohomophones that converged in meaning on one nonpresented item, JO correctly selected the nonpresented item associated with all PHs on the list 9 out of 10 times (e.g., selected *smell* instead of *rose*). Of the 270 total trials presented in the recognition paradigm following each forced choice

trial, JO accurately identified 212 words (79%). With respect to the 140 real word PEs of previously presented PHs included in the recognition paradigm, JO correctly recognized 92 targets (66%). She falsely recognized only 10 of 130 semantically related foils (8%). These findings indicate that JO was able to discriminate between real word equivalents of previously read PHs and other semantically related words. In addition, given recognition accuracy well above the level of performance demonstrated for correct PH reading (26%), these results strongly suggest JO was able to reliably access phonological information with additional semantic information and discriminate fine-grained semantic relationships at an explicit level, despite the requirement to read list PHs aloud.

Importantly, analysis of the pattern of PH reading with respect to subsequent recognition performance suggests better ability to recognize previously accessed PHs than is evident from examining her overall performance scores alone. Specifically, of the 48 total false rejections (i.e., word targets that were previously presented as PHs but not subsequently recognized during the recognition trials), 26 were the real word PEs of PHs that resulted in no responses during the prior reading task (i.e., Experiment 5 Naming Task). This finding indicates that poor recognition for these items was due to impaired initial access during naming rather than an inability to discriminate this semantic information in a recognition paradigm. In this context, it is interesting to note that if we consider only real word PEs that initially resulted in a word response during PH reading (regardless of response type---correctly identified, semantic errors, phonological errors, morphological errors, and orthographical errors, as well as short circumlocutions), JO correctly recognized 80% of previously processed PHs (86 out of 108 targets). The number of accurately recognized real word PEs of previously processed PHs increases to

91% if only PHs that were correctly identified or resulted in semantic errors during the naming task are analyzed (60 out of 66 targets). This pattern of reading and subsequent recognition ability argues against an interpretation of PH naming performance that hinges on orthography reliance. Specifically, JO's recognition performance suggested differential sensitivity to the degree she successfully processed the PHs: Despite the visual similarity of PHs and real word PEs overall, she generally recognized only those real word PEs to PHs from which she was initially able to derive semantic information. This finding strongly implicates the role of semantics in mediating explicit access to assembled PHs.

The results of the forced-choice trials in Experiment 4 and 5 clearly indicate that JO is able to access assembled phonology and derive semantic information from PHs in order to discriminate semantic information at an explicit level. Analysis of reading responses to PHs and subsequent ability to recognize real word PEs indicates sufficient sensitivity to this information to support recognition for previously presented lexical information. This finding strongly suggests that JO was able to explicitly differentiate activation levels and access specific lexical entries, regardless of the fact that she generated errors in response to this activation during naming. If JO is capable of accessing specific lexical entries at an explicit level despite the generation of errors during production, then she should be able to differentiate between lexical entries and the errors she produced, even for the most fine-grained semantic distinctions.

Experiment 6: Recognition Memory for Semantic Distinctions

In order to maximize the likelihood of semantically related responses, the stimulus set consisted of 58 monosyllabic words that resulted in semantic errors during previous

reading tasks with JO (see Appendix 4 for this stimulus set). These words were randomly divided into four smaller reading groupings (two contained 14 words and two contained 15 words). For each grouping, JO was asked to read each word aloud. Each word was individually printed in 16-point font on 3X5 index cards. The task was participant paced and no time limits were imposed. After a five-minute delay, JO was presented with a recognition task that included each word in the grouping, any semantic errors she just produced in response to each word in the grouping, and other non-semantically related foils. JO was simply asked to indicate with a yes or no response whether the word was previously presented during the reading task.

Experiment 6: Results and Discussion

As first responses, JO correctly read 28 of the 58 targets and produced 19 semantic errors. In addition, JO produced phonological, morphological, and orthographical errors, as well as short circumlocutions and one no response (see Table 9). Although this stimulus set resulted in an disproportionately large number of correct responses and semantic errors, as was expected given the selection requirement for inclusion (i.e., that she had previously generated a semantic error in response to each word and therefore certainly accessed associated semantic information), the pattern of errors overall is consistent with her typical performance and with the classic deep dyslexia profile.

Table 9. Proportion of Errors for Semantic Lists

Error type	Error proportion
Orthographic	1/58
Phonological/orthographic	2/58
Morphological	4/58
Semantic	19/58
Other	3/58
No attempt*	1/58
Total Errors	30/58

Note. "**No attempt" responses are items that JO indicated she could not read either by saying "no" or "I don't know."

Of the 142 total trials presented in the recognition paradigm following each list, JO accurately identified 137 words (96%). With respect to the 58 list words, JO correctly recognized 55 targets (95%). She falsely recognized only 1 of the 34 semantically related foils (i.e., the semantic errors she produced in response to the list words during the reading task)³ and 1 of the 50 non-semantically related foils. These findings indicate that JO was able to discriminate between previously presented list words and the semantic errors she generated in response to these words with very high accuracy. These results strongly suggest intact ability to explicitly differentiate activation levels of fine-grained semantic distinctions and access specific lexical entries, despite the generation of errors during production.

³ Across the four groupings of words, JO produced a total of 34 semantic errors: She typically produces several reading responses to words she does not initially correctly identify and all semantic errors produced under these conditions were included as semantically related foils in the recognition paradigm.

GENERAL DISCUSSION

The FIT posits a theoretical distinction between explicit and implicit access in deep dyslexia. Specifically, this view argues that reading errors are due to impaired explicit access and subsequent production due to slowed or reduced inhibitory connections. Previous research (e.g., Colangelo et al., 2004; Colangelo & Buchanan, in press) is consistent with this model: By manipulating semantic context, the blocking paradigm provided clear support for the distinction between implicit and explicit access at the task level. However, in order to demonstrate that this distinction also exists at the level of the representation, performance must be shown to dissociate based on explicit and implicit task demands for word level semantic variables (e.g., number of semantic neighbourhoods). To test for this distinction, Experiment 1 capitalized on the fact that some orthographic representations correspond to multiple meanings (e.g., *bank*) and thus are semantically ambiguous. Given multiple representations in the semantic system, these words are linked to several distinct semantic neighbourhoods. In contrast, unambiguous words correspond with only one concept (e.g., *food*) and therefore are consistently associated with one semantic neighbourhood. Based on the assumption that ambiguous and unambiguous words are associated with a different number of semantic neighbourhoods, the FIT predicts that these words should differ with respect to explicit lexical access.

Given that ambiguous words are associated with multiple semantic neighbourhoods and a correspondingly large number of candidates available for potential selection, the finding for increased semantic errors in response to these words relative to unambiguous words during aloud reading in Experiment 1a provide support for failure of

inhibition as the mechanism of impaired access. However, the effects of failed inhibition are only assumed in conditions that have an explicit selection requirement. In contrast, the FIT proposes that implicit access to semantic information is intact in deep dyslexia. Evidence for intact implicit semantic access was provided by the results of Experiment 1b, which showed better accuracy for ambiguous compared with unambiguous words in lexical decision (consistent with the normal effect). Cumulatively, the results of the ambiguity manipulation for aloud reading and lexical decision in Experiment 1 provide evidence for a dissociation in performance given word level semantic variables based on explicit and implicit task demands. These findings not only support the distinction between explicit and implicit semantic access at the level of the representation, but also implicate failure of inhibition as the mechanism of impaired explicit access.

Impaired performance on a task of aloud reading provides support for impaired semantic access at the explicit level (Experiment 1a). However, given that aloud reading requires both explicit access to a particular representation in the semantic system, as well as access to the phonological output lexicon in order to support an oral response, the effects of semantics and phonology on aloud reading performance are confounded. In order to definitely determine that explicit access to *semantic information* is impaired in deep dyslexia (as was implied by divided visual field research) and localize damage to the level of semantics within the functional architecture of the language system, performance must be examined given task demands for explicit semantic access *without* production. Contrary to expectation based on the divided visual field results (but consistent with the FIT), the results from experiment 2 provided clear evidence for intact explicit access to semantic information in deep dyslexia: In total, JO correctly selected the converged word

in 87% (39/45) of the forced choice trials, which indicates that she was able to reliably access and discriminate semantic relationships at an explicit level when production was not required. Together, the findings from Experiment 2 strongly imply that the damage in deep dyslexia is at the next level of representation and processing: the phonological output lexicon.

The fact that deep dyslexics are generally very impaired at nonword reading is consistent with localized damage to the phonological output lexicon: According to the FIT, impaired explicit access to assembled phonology results from grossly impaired ability to discriminate activation levels of phonological neighbours because regular nonwords lack any lexical representation to assist in selecting appropriate candidates in the phonological output lexicon. Thus, the FIT predicts that any manipulation that boosts the level of activation of specific phonological candidates should facilitate selection in the phonological output lexicon. In order to investigate this postulation, studies 3 through 5 capitalized on the special status of a particular type of nonword: the pseudohomophone. Specifically, the assembled phonology of pseudohomophone nonwords is linked to semantic representations through feedback connections from the phonological output lexicon to the semantic system. Semantic activation associated with pseudohomophones boosts the activation levels of candidates with consistent phonology, thereby substantially constraining the number of potential options available for selection relative to regular nonwords. The questions explored in the pseudohomophone experiments (3 through 5) focused on whether this semantic activation is sufficient to support explicit access to consistent assembled phonology. The results of previous studies with deep dyslexics given pseudohomophone naming suggest that this might be the case: These patients

showed better reading of pseudohomophones (e.g., *jeap*) relative to regular nonwords (e.g., *frip*, see Buchanan, Kiss, and Burgess, 2000; Buchanan et al., 2003). However, if semantic activation is sufficient to support explicit access to consistent assembled phonology there should also be evidence for comparable reading performance for pseudohomophones (e.g., *rawky*) and their real word equivalents (e.g., *rocky*) in deep dyslexia. The results of Experiment 3 were consistent with this prediction. Using forced choice and recognition procedures, Experiments 4 and 5 extended this examination by demonstrating that the semantic information derived from pseudohomophones was not only sufficient to support access but also to discriminate associated semantic information at an explicit level. Cumulatively, these results indicate that deep dyslexics are capable of assembling phonology and explicitly differentiating semantic information associated with consistent phonological entries, despite generating errors to these same representations under conditions that require production. These findings suggest a distinction between processes associated with semantic access and those related to production. Further evidence for preserved semantic sensitivity in the context of impaired production was provided in Experiment 6: JO showed high accuracy in a task that required her to distinguish between word representations and the semantic errors she produced in response to those representations after a delay. These results clearly demonstrate that this deep dyslexic patient was able to discriminate very fine-grained semantic information and access specific semantic entries at an explicit level, even though she generated selection errors during production.

The results of the current research program suggest that deep dyslexics have normal access to information in the semantic system. In addition, JO's performance on

the pseudohomophone semantic decision tasks showed that deep dyslexics can access assembled phonology on an explicit level. However, these tasks specifically required the processing of semantic information and therefore strongly relied on semantic context to mediate performance (i.e., all pseudohomophones were presented in semantically related categories). To date, the ability to process phonological relationships on an explicit level without assistance from semantics has not yet been demonstrated in deep dyslexia.

Although not formally part of this dissertation, the following sections review several follow up studies that further elucidate the location of damage in deep dyslexia and provide important theoretical contributions to understanding processing in the normal language system.

EXPLICIT ACCESS TO PHONOLOGY AND BEYOND: A PEEK INTO FUTURE RESEARCH...

Explicit Phonological Processing

As reviewed above, previous demonstrations of intact explicit access to phonology in deep dyslexia have relied on information provided from semantics. In fact, in all previous tasks, JO's attention was specifically focussed on the semantic content while her ability to process phonology was indirectly assessed (i.e., she was asked to make *semantic* decisions based on pseudohomophone information). Although her performance was clearly mediated by intact ability to assemble phonology, it remains to be seen whether JO can make *phonological* decisions on an explicit level when semantic information is rendered completely irrelevant. Domen, Colangelo, and Buchanan (in preparation) investigated this question using a stimulus set that included 32 phonological lists, each comprised of 4 orthographically diverse words (i.e., words that reduce visual similarity but rhymed with one another e.g., *pier*, *deer*, *year*, and *here*). Each list was followed by a forced choice trial that included two orthographically similar options, one that rhymed with all other words on the list (e.g., *ear*) and one that did not (e.g., *bear*). JO was simply asked to read each list silently and select the option that rhymed with all other words on the list. The task was participant paced and no time limits were imposed. The results of this investigation showed that JO selected the rhyming option on 23 of the 32 forced-choice trials, Fisher Exact Probability Test, $p = 0.06$. These results provided support for better ability to process phonological relationships on an explicit level without direct assistance from semantics than is suggested by her nonword reading performance. In combination with the findings of earlier studies that indicated a distinction between

explicit access and errors generated during production, these results suggest that the reading impairment in deep dyslexia is beyond the level of explicit access in the phonological output lexicon. In fact, these results suggest the contribution of articulation processes to impaired reading in deep dyslexia.

What about Articulation, Anyway?

Extant explanations of deep dyslexia have generally attributed locations of damage in the language system transparently: Semantic errors have been assumed to reflect damage to the semantic system, whereas poor nonword reading has been assumed to reflect damage to subword assembly processes. As such, no account has addressed the potential effects of the production difficulty of target words on reading performance. Recently, Bose, Colangelo, and Buchanan (in preparation) investigated this variable in reading and repetition tasks for words presented in semantically blocked (i.e., grouped by semantic categories “*table, sit, legs, seat, couch, desk, etc.*”) and unblocked (i.e., items presented in random order, “*rye, truck, table, village, etc.*”) conditions. This manipulation allowed examination of the relationships between semantic and production complexity and the extent to which input modality mediates these effects.

The data set included the same 300 words discussed in Colangelo et al. (2004). For each word, the Index of Phonetic Complexity (IPC) was calculated as a metric of phonetic complexity (Jakielski, 1998). In this system, each word is assigned a sum of scores along eight different factors: consonant by place, consonant by manner, singleton consonants by place, vowel by class, word shape, word length, contiguous consonants, and cluster by place. Based on the total IPC score, words were categorized as either simplex or complex. Error rate according to phonetic complexity was conducted for each

of the following two stimuli sets: The responses to the reading task initially presented in Colangelo et al., 2004 and a follow-up study that presented these same words in a repetition task. Each modality (reading and repetition) was examined for both semantically blocked versus unblocked conditions (see Table 10 for Number of Errors for these conditions).

Table 10: Number of Errors for Reading and Repetition

Modality	Conditions	
	Random	Ordered
Reading	127/300=42.33%	159/300 =53%
Repetition	33/300= 11%	37/300= 12.33%

This analysis revealed an effect of phonetic complexity with complex words resulting in more errors than simple words. There was also an effect of input modality with reading being more impaired than repetition. These factors were shown to relate such that the interaction between phonetic complexity and semantic blocking was more pronounced in the reading than the repetition task (see Figure 2).

Figure 2. The Relationship between Semantic and Phonetic Complexity for Modality

The interaction of semantic blocking with phonetic complexity suggests that semantic processes are constrained by output production characteristics and that this is greater when production is required from visual rather than auditory targets. These results suggest that flow of information is not strictly serial, but rather that unselected semantic nodes activate phonological representations. After all, the number of errors to phonetically complex words was greater for semantically blocked compared to unblocked conditions, suggesting that activation from non-target but semantically related words impacted production processes. As such, these findings are consistent with cascade models of speech production (e.g., Costa, Caramazza, & Sebastian-Galles, 2000; Cutting & Ferreira, 1999; Jescheniak & Schriefers, 1998; Martin, Dell, Saffran, & Schwartz, 1994; Peterson & Savoy, 1998), which posit that unselected lexical nodes activate phonology (as opposed to serial models that claim that only the selected node can activate phonology e.g., Levelt et al., 1991). In fact, the findings from the current study suggest an intricate cascade of processing from orthographic input through semantic activation to motor movements.

THE RIGHT HEMISPHERE HYPOTHESIS FOR DEEP DYSLEXIA REVISITED

In order to explain the pattern of errors in reading performance, most models of deep dyslexia assume multiple loci of damage in the reading system. In contrast, Buchanan et al. (2003) proposed that damage in the phonological output lexicon alone accounted for the various types of reading errors observed in deep dyslexia. According to this view, reading errors occur because all associated candidate representations are activated via spread of activation in the semantic system. Through feedforward connections, these candidates are also activated in the phonological lexicon but are not subsequently pruned through inhibition, as in an intact system. Therefore, slowed or reduced inhibitory connections result in decreased sensitivity to the activation levels of neighbours and impaired explicit access. This reduced inhibition increases the likelihood that neighbours are incorrectly selected for response. Previous research (e.g., Colangelo et al., 2004; Colangelo & Buchanan, in press) and the results of the current investigation are consistent with failed inhibition localized in the phonological output lexicon and implicate the involvement of associated production processes. In order to posit neurologically plausible substrates for this mechanism it is necessary to extend our examination to incorporate findings from word recognition studies with normal participants and include other models of deep dyslexia.

The results from divided visual field studies with neurologically intact participants and patients with left hemisphere lesions suggest that the right hemisphere view of deep dyslexia is reconcilable with a failure of inhibition account for semantic errors. Specifically, divided visual field studies converge to suggest that the left hemisphere rapidly activates a broad range of semantic information then narrows activation to focus

on highly related semantic information. Narrowed activation involves the selection of strongly related meanings and inhibition of other potential candidates at later stages of lexical processing. In contrast, the right hemisphere appears to sustain activation for a broad range of semantic information over time. Studies with left hemisphere patients showed automatic activation for a broad range of semantic information, but diminished ability to select among semantically related lexical competitors and use contextual information to inhibit inappropriate meanings over time. As applied to deep dyslexia, if the left hemisphere is responsible for selective and inhibitory processes, then it is entirely plausible that semantic errors during aloud reading reflect insensitivity among candidates resulting from sustained broad semantic activation when the left hemisphere is damaged and inhibition fails, thus resulting in right hemisphere reading performance. However, as semantic activation would then be similar in both hemispheres, it is not clear at this time which hemisphere would predominate during semantic processing in deep dyslexia.

Another unresolved issue is the exact location of inhibitory processes in the language system (e.g., semantic versus phonological output system, or both). The cumulative results of divided visual field research suggest that the left hemisphere mediates inhibition, and that the suppression of less likely candidates occurs in the semantic system. However, to date, the degree to which associated phonological information was also activated during these semantic manipulations is unknown and few studies have focused on the differential abilities of the cerebral hemispheres to access phonological representations of printed words, particularly with respect to the time course of activation. Thus, it is yet to be definitively determined whether inhibitory processes (and failure thereof after left hemisphere damage) are involved in explicit access in the

semantic system (as was implied by divided visual field research), explicit access in the phonological output lexicon (as was suggested by the pattern of responses in a deep dyslexic patient), or explicit access in both these components within the functional architecture of the normal language system.

Notably, the results of Bose, Colangelo, and Buchanan (in preparation) suggest that further exploring the role of phonetic complexity in constraining semantic and phonological processes may help elucidate the factors involved in reading errors, as well as inform the neurological instantiation of language processing in deep dyslexia. For example, using a divided visual field technique, Chairello, Hasbrooke, and Maxifield (1999) showed bilateral activation when unattended distractor items were phonologically related to the target word, suggesting that the right hemisphere is capable of decoding phonology from orthography. However, these authors postulated that as the computational demands of the phonological task increase, left hemisphere articulatory mechanisms are needed to maintain transiently activated phonological codes. When considered in the context of deep dyslexia, these results suggest that the right hemisphere is capable of implicit access to assembled phonology. However, explicit access to this information requires articulatory rehearsal and it is this system that is damaged in deep dyslexia, thus resulting in impaired nonword reading.

If the right hemisphere can activate phonology from orthography, but only via passive means, then this may explain the better than expected performance for pseudohomophone manipulations by the deep dyslexic in this research program: For nonwords (both regular and pseudohomophones), the right hemisphere was able to assemble phonology from orthography and support implicit access. In the case of

pseudohomophones, it is possible that feedback connections from phonology to the semantic system provided a boost to consistent phonology that was also sufficient to support explicit access in the right hemisphere. Alternatively, the additional semantic information may have maintained the phonological codes long enough to transfer them to the left hemisphere and the articulatory mechanisms available there, which then supported explicit access. However, assuming some damage to the articulation system, production was still impaired. In contrast, because regular nonwords (i.e., *slirt*) are not associated with semantic information, the phonological codes derived from orthography for these items faded too rapidly to either support explicit access in the right hemisphere or transfer this information to the left hemisphere for explicit access there. In the absence of explicit access, production was rendered completely impossible, thus accounting for very impaired performance for these items. Given the accommodation for right hemisphere ability to derive phonology from orthography, at least transiently, the results of the current series of studies are consistent with this modified view of the right hemisphere hypothesis as an explanation for deep dyslexia.

APPENDIX 1: Summary of Results for Divided Visual Field Studies

Author	SR1	SOA	L-L	R-R
Koivisto, 1997	nonassoc cat	165	priming	no priming
Abernethy & Coney, 1996	nonassoc cat	250	priming	no priming
Koivisto, 1997	nonassoc cat	250	L > R	L > R
Collins, 1999	nonassoc cat	250	priming	no priming
Abernethy & Coney, 1990	nonassoc cat	250	priming	no priming
Abernethy & Coney, 1996	nonassoc cat	450	priming	no priming
Koivisto, 1997	nonassoc cat	500	R > L	R > L
Chiarello et al., 1990	nonassoc cat	575	R > L	R > L
Chiarello 1985	nonassoc cat	600	R > L	R > L
Chiarello & Richards, 1992	nonassoc cat	600	no priming	priming
Chiarello et. Al., 2001	nonassoc cat	600	no priming	priming
Koivisto, 1997	nonassoc cat	750	no priming	priming
Collins, 1999	nonassoc cat	750	no priming	priming

Author	SR2	SOA	L-L	R-R
Richards & Chiarello, 1995	direct	50	priming	priming
Richards & Chiarello, 1995	indirect	50	priming	priming
Nakagawa, 1991	strong assoc	67	priming	no priming
Nakagawa, 1991	unrelated	67	priming	inhibition
Abernethy & Coney, 1993	assoc	250	priming	no priming
Coney, 2002	low assoc	250	priming	priming
Coney, 2002	med assoc	250	priming	priming
Coney, 2002	high assoc	250	priming	priming
Richards & Chiarello, 1995	direct	250	priming	priming
Richards & Chiarello, 1995	indirect	250	priming	priming
Abernethy & Coney, 1993	assoc	450	priming	priming
Coney, 2002	low assoc	750	priming	priming
Coney, 2002	med assoc	750	priming	priming
Coney, 2002	high assoc	750	priming	priming
Richards & Chiarello, 1995	direct	750	priming	priming
Richards & Chiarello, 1995	indirect	750	priming	priming
Livesay & Burgess, 2003	indirect	750	priming	priming
Nakagawa, 1991	strong assoc	750	priming	priming
Nakagawa, 1991	unrelated	750	inhibition	no inhibition

SR1 = Nonassociated Category Members; SR2 = Associates

Summary, Continued

Author	SR3	SOA	L-L	R-R
Audet et al., 1998	cat assoc	150	priming	priming
Chiarello et al., 2003	cat assoc	150	priming	lag
Chiarello et al., 2003	cat assoc	225	priming	priming
Chiarello et al., 2003	cat assoc	300	priming	priming
Chiarello et al., 2003	cat assoc	500	priming	priming
Chiarello et al., 1990	cat assoc	575	priming	priming
Audet et al., 1998	cat assoc	800	priming	priming
Chiarello et al., 2003	cat assoc	800	priming	priming

Author	SR4	SOA	L-L	R-R
Atchley et al., 1996	biased dom	35	priming	priming
Atchley et al., 1996	biased sub	35	priming	priming
Burgess & Simpson, 1988	dom	35	priming	priming
Atchley et al., 1996	equibiased dom	35	priming	priming
Atchley et al., 1996	equibiased sub	35	priming	priming
Burgess & Simpson, 1988	sub	35	priming	no priming
Atchley et al., 1999	dom-com	50	priming	priming
Atchley et al., 1999	sub-com	50	priming	no priming
Atchley et al., 1999	sub-incom	50	priming	priming
Chiarello et al., 1995	dom	80	priming	priming
Chiarello et al., 1995	sub	80	priming	priming
Chiarello et al., 1995	dom	130	priming	priming
Chiarello et al., 1995	sub	130	priming	priming
Chiarello et al., 1995	dom	200	priming	priming
Chiarello et al., 1995	sub	200	priming	priming
Atchley et al., 1996	biased dom	300	priming	priming
Atchley et al., 1996	biased sub	300	priming	priming
Atchley et al., 1996	equibiased dom	300	priming	priming
Atchley et al., 1996	equibiased sub	300	priming	priming
Atchley et al., 1996	biased dom	750	priming	priming
Atchley et al., 1996	biased sub	750	inhibition	priming
Burgess & Simpson, 1988	dom	750	priming	priming

SR3 = Category Associates

SR4 = Ambiguous Words

Dom = Dominant Meaning

Sub = Subordinate Meaning

Summary, Continued

Author	SR4	SOA	L-L	R-R
Atchley et al., 1999	dom-com	750	priming	priming
Atchley et al., 1996	equibiased dom	750	priming	priming
Atchley et al., 1996	equibiased sub	750	priming	priming
Burgess & Simpson, 1988	sub	750	inhibition	priming
Atchley et al., 1999	sub-com	750	priming	priming
Atchley et al., 1999	sub-incom	750	no priming	priming
Faust & Lavidor, 2003	dom-converge	800	priming	priming
Faust & Lavidor, 2003	dom-diverge	800	no priming	priming
Faust & Lavidor, 2003	sub-converge	800	priming	priming
Faust & Lavidor, 2003	sub-diverge	800	no priming	priming

SR4 = Ambiguous Words

Dom = Dominant Meaning

Sub = Subordinate Meaning

APPENDIX 2: Stimulus Sets

Stimulus Set for Experiment 2a

bug	dinner	round	petals	stomach	wood	fly	white
insect	eat	throw	smell	ache	chalk	nest	cold
gross	meal	basket	pot	dancer	surf	parrot	ice
disgusting	sandwich	game	bloom	fat	room	eagle	flake
motel	noon	bounce	beauty	beer	game	feather	rain
pest	hungry	dance	blossom	food	nail	wings	plow
spray	supper	football	color	scratch	plane	canary	ski
ant	breakfast	soccer	seed	tight	school	sing	winter
brown	hour	hit	child	up	ship	blue jay	hail
kill	salad	park	perfume	big	walk	tree	ball
dirt	soup	boy	stem	hairy	black	cage	north
food	restaurant	chain	sun	jelly	boat	robin	freeze
spider	drink	jail	tree	body	build	song	shovel
yuck	food	red	vase	pot	bulletin	dove	fort
crawl	date	sport	grow	jiggle	skate	seagull	storm
cock	lunch	base	flower	belly	bill	bird	snow
roach	pail	ball	bed	button	board	house	man
bottom	clean	ring	fire	cold	birthday	jam	cob
high	dry	tower	tree	tub	eat	toast	husk
down	clothes	liberty	burn	warm	pie	bread	yellow
hat	car	church	forest	steam	icing	doughnut	food
above	clothes	school	log	sweat	food	grape	eat
spin	hand	noise	stove	dog	bake	roll	field
cover	soap	sound	grain	heat	good	butter	bread
dog	tub	alarm	metal	humid	mix	jar	butter
gun	bath	gold	oak	beach	frosting	soft	vegetable
shirt	wax	leave	splinter	oven	sweet	sweet	flake
up	dirty	chime	bark	fire	party	berry	grill
mountain	face	tinker	board	pepper	cookie	spread	foot
tip	tube	wedding	brick	chocolate	cream	belly	kernel
peak	wear	cow	chair	summer	yummy	breakfast	oil
toy	water	blue	table	boil	diet	knife	frozen
table	wash	dumb	wood	hot	short	jelly	pop
top	basin	bell	work	rod	cake	belly	corn

Stimulus Set for Experiment 2a, Continued

bug	college	foot	ground
insect	book	sock	golf
airplane	desk	lace	dig
mosquito	learn	horn	deep
swatter	gym	boot	dirt
pest	student	fit	fall
soup	pen	sneaker	rabbit
paper	teacher	string	button
soar	class	sandals	dark
bird	education	size	doughnut
dirty	library	salesman	large
away	backboard	sole	round
picnic	friend	tie	space
roach	grade	tree	circle
wings	chalk	tongue	mole
butter	school	shoe	pot
fly	yard	horn	hole

Stimulus Set for Experiment 2b

insect	drunk	slow	heat	fellow	law	man	army
wing	beer	river	pipe	narrow	courts	person	obey
bird	liquor	Jonathan	cook	John	judge	American	officer
fly	gin	current	warm	time	right	country	performance
yellow	bottles	rapid	fire	far	liberty	alien	do
net	alcohol	stream	oven	hair	government	people	tell
flower	rye	water	wood	island	jury	vote	general
bug	glass	quick	kitchen	road	truth	melody	shout
cocoon	wine	Gulliver	lid	thin	blind	patriot	halt
summer	rum	run	coal	underwear	fair	flag	voice
color	bourbon	sure	gas	distance	supreme	foreigner	soldier
bee	evil	deer	iron	line	crime	France	harsh
stomach	bar	car	range	low	department	immigrant	attention
worm	scotch	swift	furnace	rope	trial	citizen	sharp
butterfly	whiskey	author	stove	long	justice	member	command

Stimulus Set for Experiment 2b, Continued

pretty	sound	pin	American	rest	stream	food	crowded
girls	piano	eye	symbol	awake	lake	eat	state
woman	sing	sewing	stars	tired	Mississippi	sandwich	capital
homely	radio	sharp	anthem	dream	boat	rye	streets
lovely	band	point	stripes	wake	tide	jam	subway
nice	melody	prick	pole	snooze	swim	milk	country
picture	horn	thimble	wave	blanket	flow	flour	New York
lady	concert	haystack	raised	doze	run	jelly	village
mountain	instrument	thorn	national	slumber	barge	dough	metropolis
snow	symphony	hurt	checkered	snore	creek	crust	big
scene	jazz	injection	emblem	nap	brook	slice	Chicago
music	orchestra	syringe	sign	peace	fish	wine	suburb
day	art	cloth	freedom	yawn	bridge	loaf	county
gorgeous	music	needle	flag	sleep	river	toast	urban
beautiful	rhythm	kitting	pendant	drowsy	winding	bread	city

lettuce	train	valley	saucer
vegetable	noise	climb	tea
food	sing	summit	measuring
salad	blow	top	coaster
green	tune	molehill	lid
garden	sound	peak	handle
leaf	dog	plain	coffee
sauerkraut	song	glacier	straw
smell	shrill	goat	goblet
slaw	boy	bike	soup
patch	lips	climber	stein
plant	wolf	range	drink
carrots	call	steep	plastic
soup	loud	mountain	sip
cabbage	whistle	ski	cup

Stimulus Set for Experiment 2b, Reading Task

candy	dark	husband	waste	robber
sugar	cat	uncle	can	crook
bitter	charred	lady	refuse	burglar
good	night	mouse	sewage	money
taste	funeral	male	bag	cop
tooth	color	father	junk	bad
nice	grief	strong	rubbish	rob
honey	blue	friend	sweep	jail
soda	death	beard	scraps	gun
chocolate	ink	person	pile	villain
heart	bottom	handsome	dump	crime
cake	coal	muscle	landfill	bank
tart	brown	suit	debris	bandit
pie	black	man	trash	thief
sweet	gray	old	litter	criminal

Stimulus Set for Experiment 3

Word	PH	Word	PH	Word	PH
aroma	arohma	twilight	twilite	fragrance	fragrence
drowse	drouse	battle	battel	grass	gras
fabric	fabrick	beverage	bevurage	green	grean
leader	leadur	buddy	budy	head	hed
blade	blaide	charge	charg	knife	nife
brochure	broshure	cocktail	coktail	odour	oder
conflict	konflikt	companion	cumpanion	rain	rayn
container	containar	comrade	comrad	razor	razer
dagger	daggur	dipper	dippur	shower	showur
drizzle	drizzel	melody	melady	smell	smel
ladle	ladel	refuse	refuze	sod	sawd
lyric	lyrik	rubbish	rubish	trousers	trousars
scalpel	scalpal	scoop	skoop		
slacks	slaks	slumber	slumbur		
struggle	struggle	snooze	snooz		
friend	frend	sundown	sondown		
pebble	pebbel	tune	toon		
sprinkle	sprinkel	turf	terf		
drawers	drawurs	waste	waiste		
garbage	garbig	boulder	bouldar		
pamphlet	pamflit	captain	captin		
combat	kombat	carton	cartin		
highball	highbal	case	kase		
leaflet	leaflit	chief	cheef		
nightfall	nitefall	evening	evining		
sunset	sonset	fight	fite		

Stimulus Set for Experiment 4

sik	pensil	englind	smoothe	madd	sleaves	shew
hapiness	foutan	croun	bumpee	feer	tye	kic
welth	bick	prinse	tuf	haite	buttun	sandels
ilness	scribbel	dictatur	sandpaiper	raige	coller	socer
doctur	crayin	palase	jaggid	tempur	pockit	ankel
servis	cros	ches	redy	furey	belte	bewt
hospitel	markur	subjec	corse	rath	linin	socer
disease	captin	monarc	beerd	happie	jeen	smel
vigur	lettur	royel	ruggid	fite	jackit	sneeker
centur	kap	leeder	sandie	hatrid	slaks	sise
paine	desc	powur	bords	meen	dres	soal
whell	spel	casel	buly	kalm	rinkle	heele
liv	klass	jewel	lumpee	luv	wair	nale
nurs	chawk	prinsess	gritt	teers	tuk	stule
health	pen	reign	gravel	enrage	shirt	mouth
robust	letter	king	rough	anger	cuffs	foot

taybul	wharm	tigur
leggs	wintur	circus
seet	friged	jungel
reclinur	chily	taimer
kushion	heet	kub
stule	weathur	maine
siting	freese	roor
rockur	shivur	fierse
kitchin	artic	klaw
flor	summur	animel
lapp	sneez	beest
hed	sik	teath
offis	kool	wilde
mann	skarf	pownce
chair	frost	lion
bench	cold	pride

Stimulus Set for Experiment 5

howse	glas	breeth	pillo	nerse	craul	sower
laik	shaid	snif	lowd	sic	feete	taist
chease	sil	heer	cottun	medisine	stickey	chocolat
kabin	curtan	whif	furr	helth	beatle	lemin
smal	fraim	reak	fether	hospitel	gros	asid
dor	breaze	flowurs	kiten	offis	blak	almunds
fense	screan	awfull	kuddle	ded	scarie	kandy
wuds	wud	sence	baybee	hert	rowch	suger
rowse	miror	sneez	smoothe	paine	fobia	kream
kamp	lok	skunc	wharm	disease	tenticle	tung
piket	nob	baik	brest	kare	afrade	flavur
mountan	handel	oder	velvit	fevur	frite	lyme
cuntry	jamm	gud	silke	kough	moskeeto	feer
tiney	klear	nostrel	kushion	pil	creapy	raine
hut	shutter	smell	tender	doctor	spider	fruit
cottage	window	rose	soft	cure	small	bitter

clouds	appel	truk
tawl	vegatable	automobel
towur	sitrus	vehicel
bilding	bery	jeap
clif	chery	raice
skie	baskit	weel
plaine	juise	spead
elevater	salid	stear
spaice	sweete	braik
under	eate	pedel
loftee	kan	geer
flie	graipe	streat
ovur	creem	dashbord
skool	peech	traval
high	car	cocktail
elevate	taxi	fruit

APPENDIX 3: Ambiguous and Unambiguous Stimuli for Experiment 1 and Their Kucera and Francis Frequency and Letter Counts.

Ambiguous Words			Unambiguous Words		
	Frequency	Letter count		Frequency	Letter count
ATE	16	3	STALL	18	5
BEND	24	4	WAKE	23	4
BET	20	3	PALM	22	4
BITE	10	4	BLUFF	8	5
BLOAT	8	5	GRAVE	33	5
BOLD	21	4	HAIL	10	4
BUZZ	13	4	TICK	3	4
CHAIN	50	5	PET	8	3
CHANCE	131	6	TIP	22	3
CURVE	45	5	STAR	25	4
DEEP	109	4	DRAG	15	4
DISH	16	4	SHED	11	4
DISK	25	4	LAND	217	4
DRAIN	18	5	LEAN	20	4
DUKE	11	4	ACE	15	3
DUSK	9	4	SWITCH	43	6
FAME	18	4	DUCK	9	4
FEAR	127	4	FIELD	274	5
FORCE	230	5	SINK	23	4
GRAIN	27	5	VAULT	2	5
GROWN	43	5	SPADE	10	5
HITCH	5	5	FINE	161	4
HUG	3	3	FOIL	20	4
HUNT	10	4	LIGHT	333	5
JOLT	4	4	TAG	5	3
JUMP	24	4	BAT	18	3
LARGE	361	5	GRADE	35	5
LINT	4	4	LOAF	4	4
LOUD	20	4	MATCH	41	5
LOVE	232	4	MINT	7	4
MAZE	6	4	MISS	258	4
MEAT	45	4	SPRING	127	6
MIND	325	4	STEER	9	5

Ambiguous and unambiguous stimuli for Experiment 1, Continued

Frequency Letter count			Frequency Letter count		
PIG	8	3	BOLT	10	4
PLUG	23	4	HOG	3	3
PLUMB	5	5	RAM	2	3
POND	25	4	BOOT	13	4
RAIN	70	4	ROCK	75	4
REV	33	3	BOWL	23	4
RICE	33	4	ROLL	35	4
RUM	3	3	ROW	35	3
SANE	8	4	SACK	8	4
SHOE	14	4	TIRE	22	4
SOAP	22	4	BUCK	20	4
SOUP	16	4	HOUND	7	5
SPENT	104	5	CHARGE	122	6
STACK	9	5	CHEST	53	5
STEAK	10	5	COAST	61	5
STEAM	17	5	DASH	11	4
STORM	26	5	POUND	28	5
STREAM	51	6	DATE	103	4
STRIFE	6	6	JERK	2	4
STUCK	23	5	JOINT	39	5
STUFF	32	5	DECK	23	4
SWEPT	34	5	PUNCH	5	5
SWORN	5	5	SCREEN	48	6
TEA	28	3	STICK	39	5
TEE	5	3	DRAFT	24	5
TENT	20	4	WATCH	81	5
TOWN	212	4	STRIKE	50	6
TURF	3	4	TYPE	200	4
VALVE	3	5	SEAL	17	4
WASH	37	4	STRIP	30	5
WORTH	94	5	SWAMP	5	5
Average	46.70313	4.296875	Average	47.23438	4.359375

***Please see Borowsky & Masson, (1996) for further details regarding this stimulus set.**

APPENDIX 4: Kucera and Francis Frequency and Concreteness Counts

Stimuli for Exp 2a

WORD	CNC	KFFRQ	WORD	CNC	KFFRQ
COLLEGE	554	267	BEAUTY	336	71
BOOK	609	193	BLOSSOM	559	7
DESK	583	65	COLOR	467	141
LEARN	370	84	SEED	611	41
GYM	597	2	CHILD	581	213
STUDENT	549	131	PERFUME	-	10
PEN	571	18	STEM	556	29
TEACHER	569	80	SUN	617	112
CLASS	-	207	TREE	604	59
EDUCATION	320	214	VASE	595	4
LIBRARY	564	62	GROW	409	63
BACKBOARD	-	-	FLOWER	584	23
FRIEND	450	133	BED	635	127
GRADE	338	35	STOMACH	617	37
YARD	553	35	ACHE	443	4
DINNER	542	91	DANCER	558	31
EAT	486	61	FAT	540	60
MEAL	602	30	BEER	587	34
SANDWICH	-	10	SCRATCH	523	9
NOON	-	25	TIGHT	425	28
HUNGRY	439	23	UP	400	1895
SUPPER	563	37	BIG	-	360
BREAKFAST	576	53	HAIRY	-	5
HOURL	375	144	JELLY	560	3
SALAD	595	9	BODY	568	276
SOUP	615	16	POT	584	28
RESTAURANT	583	41	JIGGLE	-	-
DRINK	549	82	BELLY	630	23
DATE	514	103	BUTTON	613	10
LUNCH	552	33	WOOD	606	55
PAIL	538	4	CHALK	634	3
ROUND	438	81	SURF	527	1
THROW	400	42	ROOM	566	383
BASKET	606	17	GAME	477	123
BOUNCE	-	8	NAIL	598	6

Stimuli for Experiment 2a Continued

WORD	CNC	KFFRQ	WORD	CNC	KFFRQ
DANCE	502	90	PLANE	535	114
FOOTBALL	584	36	SCHOOL	573	492
SOCCER	524	3	SHIP	615	83
HIT	-	115	WALK	452	100
PARK	579	94	BLACK	470	203
BOY	609	242	BOAT	637	72
CHAIN	595	50	BUILD	402	86
JAIL	590	21	BULLETIN	-	18
RED	501	197	SKATE	562	1
SPORT	-	17	BILL	528	143
BASE	441	91	BOARD	565	239
PETALS	-	-	FLY	525	33
SMELL	450	34	NEST	557	20
BLOOM	520	12	PARROT	-	1
EAGLE	616	5	COCK	611	5
EAGLE	616	5	BOTTOM	-	88
FEATHER	-	6	HIGH	371	497
WINGS	-	-	DOWN	339	895
CANARY	577	-	HAT	601	56
SING	421	34	ABOVE	-	296
BLUE	459	143	SPIN	-	5
JAY	-	15	COVER	502	88
WHITE	472	365	DOG	610	75
COLD	457	171	GUN	612	118
ICE	621	45	SHIRT	616	27
FLAKE	-	1	UP	400	1895
CLOTHES	600	89	MOUNTAIN	616	33
HAND	604	431	TIP	459	22
RAIN	600	70	CAGE	593	9
SKI	590	5	ROBIN	637	2
WINTER	499	83	SONG	514	70
HAIL	502	10	DOVE	588	4
BALL	615	110	SEAGULL	-	-
NORTH	-	206	BIRD	602	31
FREEZE	480	6	HOUSE	608	591
SHOVEL	581	5	SOAP	598	22

Stimuli for Experiment 2a, Continued

WORD	CNC	KFFRQ	WORD	CNC	KFFRQ
FORT	580	55	BATH	600	26
STORM	527	26	WAX	569	14
SNOW	618	59	DIRTY	-	36
MAN	618	1207	FACE	599	371
BUG	-	4	TUBE	581	31
INSECT	593	14	WEAR	360	36
AIRPLANE	-	11	WATER	616	442
MOSQUITO	595	1	WASH	447	37
SWATTER	-	-	BASIN	602	7
PEST	479	4	RING	593	47
PAPER	599	157	TOWER	585	13
SOAR	366	-	LIBERTY	302	46
DIRTY	-	36	CHURCH	587	348
AWAY	257	456	SCHOOL	573	492
PICNIC	-	15	NOISE	-	37
ROACH	-	2	SOUND	502	204
BUTTER	618	27	ALARM	-	16
GROSS	-	66	GOLD	576	52
DISGUSTING	-	-	LEAVE	-	205
MOTEL	-	24	CHIME	-	-
SPRAY	514	16	TINKER	-	-
ANT	604	6	WEDDING	509	32
BROWN	-	176	COW	621	29
KILL	386	63	BLUE	459	143
DIRT	564	43	DUMB	340	13
FOOD	597	147	BELL	620	18
SPIDER	607	2	TREE	604	59
CRAWL	408	11	BURN	490	15
FOREST	609	66	SHORT	351	212
LOG	-	11	CAKE	624	13
STOVE	591	15	JAM	563	6
GRAIN	-	27	TOAST	582	19
METAL	582	61	DOUGHNUT	606	-
OAK	588	15	GRAPE	611	3
SPLINTER	-	4	ROLL	457	35
BARK	563	14	BUTTER	618	27

Stimuli for Experiment 2a, Continued

WORD	CNC	KFFRQ	WORD	CNC	KFFRQ
BOARD	565	239	JAR	595	16
BRICK	610	18	SOFT	414	61
CHAIR	606	66	BERRY	573	9
TABLE	604	198	SPREAD	-	83
WOOD	606	55	BELLY	630	23
WORK	402	760	BREAKFAST	576	53
COLD	457	171	KNIFE	612	76
TUB	-	13	JELLY	560	3
WARM	-	67	COB	-	-
STEAM	552	17	HUSK	-	-
SWEAT	569	23	YELLOW	537	55
HEAT	472	97	FIELD	-	274
HUMID	-	1	BREAD	622	41
BEACH	612	61	VEGETABLE	602	10
OVEN	593	7	FLAKE	-	1
FIRE	595	187	GRILL	-	12
PEPPER	591	13	FOOT	558	70
CHOCOLATE	576	9	KERNEL	559	3
SUMMER	439	134	OIL	581	93
PEAK	-	16	FROZEN	-	27
TOY	567	4	POP	-	8
TOP	435	204	CORN	576	34
CLEAN	392	70	SOCK	581	4
DRY	-	68	LACE	545	7
CAR	622	274	BOOT	595	13
BOIL	467	12	FIT	-	75
HOT	507	130	SNEAKER	-	2
ROD	591	18	STRING	570	19
BIRTHDAY	-	18	SANDALS	-	-
EAT	486	61	SIZE	354	138
PIE	613	14	SALESMAN	-	12
ICING	-	1	SOLE	484	18
FOOD	597	147	TIE	568	23
BAKE	-	12	TONGUE	634	35
GOOD	297	807	SHOE	600	14
MIX	-	13	HORN	618	31

Stimuli for Experiment 2a Continued

WORD	CNC	KFFRQ	WORD	CNC	KFFRQ
FROSTING	-	1	GROUND	558	186
SWEET	463	70	GOLF	540	34
PARTY	496	216	DIG	-	10
COOKIE	634	1	DEEP	400	109
CREAM	621	20	DIRT	564	43
DIET	449	21	FALL	409	147
RABBIT	635	11			
BUTTON	613	10			
DARK	497	185			
LARGE	-	361			
ROUND	438	81			
SPACE	381	184			
CIRCLE	515	60			
MOLE	590	4			
POT	584	28			
HOLE	485	58			
Average	533.5	88.2	Average	545.58	111.1

Stimuli for Experiment 2b

WORD	CNC	KFFRQ	WORD	CNC	KFFRQ
INSECT	593	14	SAUERKRAUT	604	4
WING	595	18	SMELL	450	34
BIRD	602	31	SLAW	-	-
FLY	525	33	PATCH	558	13
YELLOW	537	55	PLANT	594	125
NET	577	34	CARROTS	-	-
FLOWER	584	23	SOUP	615	16
BUG	-	4	CABBAGE	611	4
COCOON	-	3	DRUNK	-	37
SUMMER	439	134	BEER	587	34
COLOR	467	141	LIQUOR	630	43
BEE	597	11	GIN	639	23
STOMACH	617	37	BOTTLES	-	-
WORM	611	4	ALCOHOL	618	13
BUTTERFLY	593	2	GLASS	635	99
PRETTY	341	107	RUM	600	3
GIRLS	-	-	BOURBON	570	8

Stimulus Set for Experiment 2b, Continued

WORD	CNC	KFFRQ	WORD	CNC	KFFRQ
WOMAN	580	224	EVIL	-	72
HOMELY	-	9	BAR	565	82
LOVELY	318	44	SCOTCH	583	5
NICE	279	75	WHISKEY	604	17
PICTURE	579	162	PIANO	615	38
LADY	564	80	SING	421	34
SNOW	618	59	RADIO	615	120
SCENE	408	106	BAND	590	53
MUSIC	512	216	MELODY	-	21
DAY	477	686	HORN	618	31
GORGEOUS	-	7	CONCERT	252	39
BEAUTIFUL	393	127	INSTRUMENT	543	47
LETTUCE	579	-	SYMPHONY	-	33
VEGETABLE	602	10	JAZZ	-	99
FOOD	597	147	ORCHESTRA	578	60
SALAD	595	9	ART	440	208
GREEN	460	116	RHYTHM	-	22
GARDEN	602	60	TRAIN	592	82
LEAF	593	12	NOISE	-	37
TUNE	464	10	BLOW	397	33
SKI	590	5	HEAT	472	97
SOUND	502	204	PIPE	602	20
DOG	610	75	COOK	502	47
SONG	514	70	WARM	-	67
SHRILL	-	7	FIRE	595	187
BOY	609	242	OVEN	593	7
LIPS	-	-	WOOD	606	55
WOLF	595	6	KITCHEN	-	90
CALL	389	188	COAL	584	32
LOUD	413	20	GAS	554	98
WHISTLE	579	4	IRON	584	43
SLOW	293	60	FURNACE	600	11
RIVER	585	165	STOVE	591	15
JONATHAN	-	5	AMERICAN	-	569
CURRENT	-	104	SYMBOL	402	54
RAPID	415	43	STARS	-	-

Stimulus Set for Experiment 2b, Continued

WORD	CNC	KFFRQ	WORD	CNC	KFFRQ
STREAM	-	51	ANTHEM	-	1
WATER	616	442	STRIPES	-	-
QUICK	343	68	POLE	577	18
SURE	281	264	WAVE	492	46
DEER	631	13	RAISED	-	101
CAR	622	274	NATIONAL	-	375
SWIFT	338	32	CHECKERED	-	-
AUTHOR	502	46	EMBLEM	-	-
PIN	600	16	SIGN	520	94
EYE	634	122	FREEDOM	277	128
SEWING	-	10	FLAG	606	16
SHARP	-	72	PENDANT	-	1
POINT	464	395	SAUCER	606	-
PRICK	-	2	TEA	609	28
THIMBLE	529	1	MEASURING	-	30
HAYSTACK	-	1	COASTER	-	-
THORN	586	3	LID	-	19
HURT	368	37	HANDLE	-	53
INJECTION	-	7	COFFEE	613	78
SYRINGE	-	1	STRAW	603	15
CLOTH	580	43	GOBLET	592	-
NEEDLE	608	15	STEIN	-	18
KITTING	-	-	DRINK	549	82
VALLEY	575	73	PLASTIC	-	31
CLIMB	-	12	SIP	-	2
SUMMIT	-	12	CUP	539	45
TOP	435	204	FELLOW	502	63
PEAK	-	16	NARROW	372	63
PLAIN	426	48	JOHN	-	362
GLACIER	590	1	TIME	343	1599
GOAT	636	6	FAR	302	427
BIKE	-	-	HAIR	583	148
CLIMBER	-	-	ISLAND	596	167
RANGE	417	160	ROAD	583	197
STEEP	-	13	MOUNTAIN	616	33
UNDERWEAR	-	3	ALIEN	399	16

Stimulus Set for Experiment 2b, Continued

WORD	CNC	KFFRQ	WORD	CNC	KFFRQ
DISTANCE	353	108	PEOPLE	540	847
LINE	477	298	VOTE	389	75
LOW	322	174	PATRIOT	-	10
ROPE	608	15	FOREIGNER	492	4
LONG	381	755	FRANCE	-	-
REST	351	163	IMMIGRANT	-	4
AWAKE	-	20	CITIZEN	455	30
TIRED	-	48	MEMBER	455	137
DREAM	386	64	EAT	486	61
WAKE	-	23	SANDWICH	-	10
SNOOZE	-	-	RYE	600	4
BLANKET	622	30	JAM	563	6
DOZE	-	-	MILK	670	49
SLUMBER	386	3	FLOUR	-	8
SNORE	-	-	JELLY	560	3
NAP	-	4	DOUGH	627	13
PEACE	309	198	CRUST	-	1
YAWN	502	2	SLICE	443	13
SLEEP	484	65	WINE	621	72
DROWSY	-	1	LOAF	-	4
LAW	349	299	TOAST	582	19
COURTS	-	-	BREAD	622	41
JUDGE	506	77	ARMY	543	132
RIGHT	361	613	OBEY	-	8
LIBERTY	302	46	OFFICER	550	101
GOVERNMENT	426	417	PERFORMANCE	409	122
JURY	540	67	DO	276	1363
TRUTH	261	126	TELL	306	268
BLIND	443	47	GENERAL	408	497
FAIR	413	77	SHOUT	471	9
SUPREME	-	51	HALT	345	10
CRIME	387	34	VOICE	485	226
DEPARTMENT	447	225	SOLDIER	578	39
TRIAL	446	134	HARSH	359	12
JUSTICE	307	114	ATTENTION	-	179
LAKE	585	54	COMMAND	377	72

Stimulus Set for Experiment 2b, Continued

WORD	CNC	KFFRQ	WORD	CNC	KFFRQ
MISSISSIPPI	-	-	CROWDED	-	-
BOAT	637	72	STATE	440	808
TIDE	516	11	CAPITAL	448	85
SWIM	482	15	STREETS	-	-
FLOW	311	67	SUBWAY	-	7
RUN	-	212	NEW	348	1635
BARGE	-	7	YORK	-	301
CREEK	-	14	VILLAGE	576	72
BROOK	611	3	METROPOLIS	504	8
FISH	597	35	BIG	-	360
BRIDGE	623	98	CHICAGO	-	-
WINDING	-	9	SUBURB	-	13
MAN	618	1207	COUNTY	-	155
PERSON	562	175	URBAN	420	42
COUNTRY	465	324			
THIN	392	92			
CITY	554	393			
Average	496.1	103.5	Average	523.0	121.4

Stimuli for Experiment 2b, Reading Task

WORD	CNC	KFFRQ	WORD	CNC	KFFRQ
CANDY	602	16	MAN	618	1207
SUGAR	620	34	OLD	349	660
BITTER	409	53	WASTE	430	35
GOOD	297	807	CAN	365	1772
TASTE	464	59	REFUSE	426	16
TOOTH	619	20	SEWAGE	-	29
NICE	279	75	BAG	603	42
HONEY	611	25	JUNK	-	8
SODA	600	3	RUBBISH	-	4
CHOCOLATE	576	9	SWEEP	476	15
HEART	605	173	SCRAPS	-	-
CAKE	624	13	PILE	504	25
TART	-	7	DUMP	502	4
PIE	613	14	DEBRIS	-	8
SWEET	463	70	TRASH	588	2
DARK	497	185	LITTER	-	3

Stimulus for 2b, Reading Task, Continued

WORD	CNC	KFFRQ	WORD	CNC	KFFRQ
CAT	615	23	ROBBER	545	2
CHARRED	-	-	CROOK	520	3
NIGHT	496	411	BURGLAR	-	1
FUNERAL	-	33	MONEY	574	265
COLOR	467	141	COP	-	15
GRIEF	303	10	BAD	308	142
BLUE	459	143	ROB	-	19
DEATH	365	277	JAIL	590	21
INK	608	7	GUN	612	118
BOTTOM	-	88	VILLAIN	-	3
COAL	584	32	CRIME	387	34
BROWN	-	176	BANK	573	83
BLACK	470	203	BANDIT	547	3
GRAY	471	80	THIEF	519	8
HUSBAND	549	131	CRIMINAL	-	24
UNCLE	580	57			
LADY	564	80			
MOUSE	624	10			
MALE	564	37			
FATHER	594	183			
STRONG	-	202			
FRIEND	450	133			
BEARD	580	26			
PERSON	562	175			
HANDSOME	-	40			
MUSCLE	573	42			
SUIT	545	48			

Average 525.1 103.6 Average 501.8 152.4

Stimuli for Experiment 3

WORD	CNC	KFFRQ	WORD	CNC	KFFRQ
AROMA	-	3	WASTE	430	35
DROWSE	-	-	BOULDER	597	10
FABRIC	565	15	CAPTAIN	534	85
LEADER	487	74	CARTON	-	-
BLADE	584	13	CASE	548	362
BROCHURE	-	2	CHIEF	503	119

Stimuli for Experiment 3, Continued

WORD	CNC	KFFRQ	WORD	CNC	KFFRQ
CONFLICT	305	52	EVENING	439	133
CONTAINER	-	10	FIGHT	455	98
DAGGER	576	-	FRAGRANCE	-	6
DRIZZLE	558	5	GRASS	599	53
LADLE	-	1	GREEN	460	116
LYRIC	-	12	HEAD	603	424
SCALPEL	-	-	KNIFE	612	76
SLACKS	-	-	ODOUR	472	-
STRUGGLE	-	62	RAIN	600	70
FRIEND	450	133	RAZOR	-	15
PEBBLE	-	1	SHOWER	588	15
SPRINKLE	-	7	SMELL	450	34
DRAWERS	-	5	SOD	569	3
GARBAGE	572	7	TROUSERS	-	7
PAMPHLET	-	3	TURF	-	3
COMBAT	-	27	TUNE	464	10
HIGHBALL	-	4			
LEAFLET	570	1			
NIGHTFALL	511	4			
SUNSET	525	14			
TWILIGHT	467	4			
BATTLE	564	87			
BEVERAGE	526	5			
BUDDY	-	13			
CHARGE	-	122			
COCKTAIL	576	25			
COMPANION	-	19			
COMRADE	497	4			
DIPPER	-	6			
MELODY	-	21			
REFUSE	426	16			
RUBBISH	-	4			
SCOOP	-	5			
SLUMBER	386	3			
SNOOZE	-	-			
SUNDOWN	-	6			
Average	503.7	20.7	Average	528.7	92.1

Stimuli for Experiment 6

WORD	CNC	KFFRQ	WORD	CNC	KFFRQ
HEEL	579	9	STEER	-	9
SAINT	458	16	BRIDE	-	33
CRISP	-	8	TASTE	464	59
TANK	581	12	SALE	364	44
BROOK	611	3	NOSE	628	60
DIME	582	4	WORK	402	760
PORCH	596	43	FLOAT	451	3
BRONZE	568	11	DRUNK	-	37
SWAMP	570	5	LAW	349	299
TAPE	564	35	GROSS	-	66
DOUGH	627	13	SWORD	577	7
COAST	562	61	COW	621	29
LAND	604	217	GRADE	338	35
SPEED	-	83	LAKE	585	54
BARN	614	29	SCARED	-	-
AUBURN	-	2	JAIL	590	21
CRACKER	-	-	BREAD	622	41
MIST	497	14	LOSE	299	58
DATE	514	103	KICK	485	16
CHURCH	587	348	BILL	528	143
GOLD	576	52	BUY	370	70
STILL	354	782	BOLD	-	21
FEET	642	283	BULL	-	14
FROWN	454	1	HILL	588	72
LEARN	370	84	STEAK	646	10
WILD	381	56	LUNG	569	16
TUBE	581	31	PLANE	535	114
FOOL	354	37	TRUST	300	52
STAGNANT	-	5	GUILT	299	33
SHINS	-	-	SILK	538	12
PURSE	572	14	DEAF	-	12
SHARK	611	-	DIVE	494	23
WOOL	608	10	WAVE	492	46
FAST	304	78	CHOIR	567	8
STICK	604	39	HERB	558	7
PORK	585	10	BALD	-	5

Stimuli for Experiment 6, Continued

WORD	CNC	KFFRQ	WORD	CNC	KFFRQ
BOOT	595	13	FILM	604	96
WATER	616	442	BRAILLE	-	1
DANCE	502	90	EYES	-	-
TRIAL	446	134	DUST	550	70
REEF	-	11	TIDE	516	11
NOISE	-	37	MINE	452	59
FEAR	326	127	SINGING	-	47
BLESS	-	9	HARP	591	1
SPEAK	419	110	MALL	459	3
PURE	-	56	MOUND	-	11
PRICE	-	108	STORE	548	74
TYPE	376	200	GLOVE	607	9
SCREAM	479	13	COIN	581	10
DEBT	416	13	Average	504.6	57.0
CALL	389	188			
TWO	383	1412			
LIVER	617	16			
VOID	-	10			
TREE	604	59			
SONG	514	70			
CLUB	509	145			
DRUM	602	11			
POOL	573	111			
COLD	457	171			
LIST	-	133			
CUT	430	192			
TUB	-	13			
PLANT	594	125			
DILL	-	12			
GAS	554	98			
TEAT	-	-			
SPACE	381	184			
FALL	409	147			
FARM	565	125			
DESK	583	65			
ILL	-	39			

Stimuli for Experiment 6, Continued

WORD	CNC	KFFRQ
BOWL	575	23
COOK	502	47
TEACHING	-	67
ROPE	608	15
RAIN	600	70
KEEP	339	264
BRAIN	556	45
BLANK	-	14
GOAT	636	6
SORE	502	10
BATH	600	26
SEAT	568	54
CLASS	-	207
TABLE	604	198
JEEP	622	16
TRUCK	595	57
CASH	547	36
SMART	304	21
Average	523.0	97.2

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