A Dual Coding Theoretical Model of Reading

Mark Sadoski

Texas A&M University

Allan Paivio

University of Western Ontario

Reference:

Sadoski, M. & Paivio, A. (2004). A dual coding theoretical model of reading. In R. B. Ruddell & N. J. Unrau (Eds.), *Theoretical models and processes of reading* (5th ed.) (pp. 1329-1362). Newark, DE: International Reading Association.

Dual Coding Theory (DCT) is an established theory of general cognition that has been directly applied to literacy. This theory was originally developed to account for verbal and nonverbal influences on memory, but it has been extended to many other areas of cognition through a systematic program of research over many years (Paivio, 1971, 1986, 1991). It has been extended to literacy as an account of reading comprehension (Sadoski & Paivio, 1994; Sadoski, Paivio, & Goetz, 1991), as an account of written composition (Sadoski, 1992), and as a unified theory of reading and writing (Sadoski & Paivio, 2001). For the fullest understanding of the theory these references and the specific studies they cite should be consulted. This paper briefly discusses the DCT account of certain basic processes in reading including decoding, comprehension, and response.

The value of explaining reading under the aegis of a theory of general cognition is compelling. Reading is a cognitive act, but there is nothing about reading that does not occur in other cognitive acts that do not involve reading. We perceive, recognize, interpret, comprehend, appreciate, and remember information that is not in text form as well as information that is in text form. Cognition in reading is a special case of general cognition that involves written language. Theories specific to reading must eventually conform with broader theories of general cognition for scientific progress to advance. DCT provides one vehicle for that advancement.

Another value offered by DCT is that it provides a combined account of decoding, comprehension, and response. Theories of reading often focus on one or another of these aspects of reading but not all. As we shall see, the same basic DCT principles apply to grapheme-phoneme correspondences, word meaning, grammar, the construction of mental models of text episodes, and even imaginative responses to text. In this chapter we will briefly explain the theory's basic assumptions; provide accounts of decoding, comprehension, and response; compare and contrast DCT with other theories of reading; and discuss its implications for practice and research.

Basic Assumptions

A basic premise of DCT is that all mental representations retain some of the concrete qualities of the external experiences from which they derive. These experiences can be linguistic or nonlinguistic. Their differing characteristics develop into two separate mental systems, or codes, one specialized for representing and processing language (the verbal code) and one for processing nonlinguistic objects and events (the nonverbal code). The latter is frequently referred to as the imagery system or code because its functions include the generation, analysis, and transformation of mental images. Each code has its own characteristic units and hierarchical organization. Together, the two codes account for knowledge of language and knowledge of the world.

The two mental codes and our five senses are orthogonal in DCT. This means that the two codes each have subsets of mental representations that are qualitatively different due to the different sensory experiences from which they originated. Because sensory systems are linked to motor response systems in perception (e.g., eye movements, listening attitudes, active touch) these subsets have sensorimotor qualities. We develop visual representations in the verbal code for language units we have seen such as letters, words, or phrases (e.g., *baseball bat*). But we also develop visual representations in the nonverbal code for nonlinguistic forms that we have seen such as common objects or scenes (e.g., a wooden or aluminum baseball bat). Likewise, we develop auditory representations in the verbal code for speech units we have heard such as phonemes and their combinations (e.g., the phoneme /*b*/, the rime /-*at*/, the word /*bat*/), and auditory representations in the nonverbal code for nonlinguistic environmental sounds we have heard (e.g., the crack of a wooden bat hitting a ball or the clink of an aluminum bat). Likewise, we develop haptic (i.e., kinesthetic or tactile) representations in the verbal code for linguistic motor acts (e.g., pronouncing /*b*/ or writing the letter *b* or touching the Braille sign for *b*), and we develop haptic representations in the nonverbal code for the active "feel" of objects, textures, and movements (e.g., the heft and swing of a baseball bat). We do not represent language in the chemical sense modalities (smell and taste), but we have nonverbal representations for them (e.g., the smell and taste of a juicy hot dog at a baseball game). Images in these modalities are typically less vivid for most people. To these should be added affect – emotional feelings and reactions. These are nonverbal by definition, although we have many names for emotional states. We also have imagery for such states, and it forms an important component of meaning. We might imagine the excitement of an enthusiastic fan at a baseball game, for example. Table 1 provides a diagram of this orthogonal relationship.

Understanding these "codes and modes" is basic to understanding the DCT interpretation of reading. The overall system can be imagined as a set of modality- and code-specific subsystems that are laced with interconnections. These subsystems are independent and appear to be specialized in certain, sometimes multiple, areas of the

Table 1

Orthogonal Relationship Between Mental Codes and Sense Modalities

	Mental Codes	
Sense Modality	Verbal	Nonverbal
Visual	Visual language(writing)	Visual objects
Auditory	Auditory language(speech)	Environmental sounds
Haptic	Braille, handwriting	"Feel" of objects
Gustatory	--	Taste memories
Olfactory	--	Smell memories

brain. For example, some persons with alexia cannot read the phrase *baseball bat* but can recognize the phrase when it is spoken and even write it, providing evidence of independent, modality-specific representations within the verbal code. Some persons with anomia can recognize a baseball bat but not be able to name it, providing evidence of a general independence between nonverbal and verbal codes. For relevant neuropsychological evidence, see Paivio (1986, 1991) and West, O'Rourke, and Holcomb (1998). Sacks (2002) provided a readable case study of neuropathology affecting only certain aspects of reading. A misunderstanding of the distinction between mental codes and sensory modalities has sometimes led to the inaccurate characterization of DCT as being about the verbal and visual codes. The correct distinctions are between verbal and nonverbal (imagery) codes, and between the visual modality and the other sensory modalities.

A common manifestation of the modular nature of our representational subsystems is seen in the phenomenon of modality-specific interference, the limited ability to do two things in the same modality at once. For example, it is difficult to listen to two conversations at once -- our verbal, auditory capacity is quickly overcome and we must "shuttle" between the two (i.e., the "cocktail-party effect"). In reading, it is somewhat difficult to visually process the print and extensively visualize its semantic content at the same time, particularly for the unskilled reader. Either the reader tends to slow down or the number of oral reading miscues increases (Denis, 1982; Eddy & Glass, 1981; Hodges, 1994; Sadoski, 1983, 1985). More discussion of this phenomenon and its implications will appear later. We will next discuss the basic units that comprise each system, their organization in each system, and the kinds of interconnections and processing operations that occur to them.

Basic Units

Cognitive theories usually specify basic units or "building blocks" of cognition. The basic units in the verbal system are *logogens,* and the basic units in the nonverbal system are *imagens.* These terms are merely jargon for the way the brain represents different types of information, but DCT assumes that they are concrete as opposed to being abstract and amodal. The terms are not meant to imply static units. Although memory representations have some permanence, they are better thought of as evolving and flexible, such as the way our vocabulary knowledge is constantly enriched by experiencing words in different contexts or the way images are often of novel scenes comprised of familiar elements.

A logogen is anything learned as a unit of language in some sense modality. Language units vary in size, although some sizes are more familiar than others (e.g., words). Hence, we have visual logogens for letters and written words and phrases; auditory logogens for phonemes and word and phrase pronunciations; haptic logogens for pronouncing, writing, or signing these language units. In speech, phonemic logogens may be represented in closely associated auditory-motor form. That is, a phoneme may be represented as a physical articulation of the speech organs as well as an auditory sound (Liberman & Mattingly, 1985).

Logogens are derived from the perception of language and influence its perception. A charming example is the child learning to say the alphabet who perceives the spoken sequence "l, m, n, o" as "elemeno." The letter-name sequence is initially perceived as one auditory-motor unit; with more learning it will be perceived as four separate units. Similarly, words can be learned before their individual letters or phonemes are learned, and words can be identified as rapidly, or more rapidly, than their individual letters or phonemes after they are learned.

Imagens are modality-specific and vary in size as well, and they tend to be perceived in nested sets. That is, mental images are often embedded in larger mental images. Hence we can visually imagine a baseball bat, the bat in the hands of a batter, and the batter at home plate in a crowded stadium. In the auditory modality, we can imagine the crack of the bat or the crack of the bat over the noise of the crowd. These perceptions may be associated into an auditory-visual mental episode that may be transformed into a sequence of the bat being swung, the crack of the bat and roar of the crowd, and the batter running to base as the ball speeds off. That is, while the imagens remain modality-specific, they can be associated into a larger mental structure that reflects the multisensory nature of physical reality.

Both types of representations can be activated in various ways. Logogens can be activated by direct sensory input such as seeing printed language, or imagens can be activated by seeing familiar objects. However, both types of mental representation can be activated indirectly, as when we spontaneously form images to words or name objects. Both internal and external contexts can also prime language or imagery. Seeing the word *baseball* can indirectly activate an internal, associated neighborhood of logogens such as *bat, glove, game, cap* and so on. All these could in turn activate related imagens. External contexts would serve to limit the activated set to the most relevant members. Therefore, both bottom-up and top-down inputs can activate mental representations in interactive ways. When enough input is received from any one source or a combination of sources, the representation is activated. What constitutes enough activation is a matter of the strength of the inputs or how often or how recently a representation has been excited. Many of these assumptions are common to most network theories of cognition, but DCT is unique in its emphasis on the modality-specific, verbal, and nonverbal distinctions in mental representation. More discussion of processing operations follows the next section.

Unit- and System-Level Organization

Logogens and the verbal system into which they are organized are characterized by sequential constraints. In all languages, units are combined into certain conventional sequences at all levels. Hence, the letters *b, a, t* can be sequenced as *bat* or *tab* but not *tba*; the words *a, baseball,* and *bat* can be sequenced as *a baseball bat* or *bat a baseball* but not *baseball a bat*, and so on. A hierarchy characterizes the verbal system such that smaller units can be sequentially synthesized into larger units (e.g., letters to words) or larger units can be sequentially analyzed into smaller units (e.g., words to letters). However, units at each level retain a degree of independence such that a spoken word, for example, can be recognized without necessarily analyzing its phonemic structure. The developmental basis of this organization is thought to be the temporally sequential nature of speech or the linear nature of print that we experience in encounters with language. A common example is that it is easier to spell a long word forward than backward from memory; the logogen is constrained by our left-to-right conventional experience (the principle is reversed in languages that are read and written right to left).

The hierarchical organization of the nonverbal system is qualitatively different. Imagens are represented and organized in a more continuous, integrated way and cannot as easily be separated into discrete elements comparable to phonemes, letters, or words. The developmental basis for this system is the generally more holistic nature of nonverbal perceptions that occur as clusters of units available simultaneously in different senses. An example is the baseball episode given earlier. We can synthesize images of smaller units (a baseball bat) into embedded or nested units (a bat in the hands of a batter) to still larger sets (the batter in a stadium with a roaring crowd), or we can analyze the scene in reverse. In the visual modality, this often takes a cinematic form where we “zoom” in or out or “cut” to a wide angle or a close-up. Dynamic, multimodal imagery sequences can also be represented, as the episode of the batter hitting the ball with a loud crack and running to first as the crowd roars.

Therefore, both the verbal and nonverbal systems have modality-specific units of various size that are hierarchically organized, but the respective units and their hierarchies are qualitatively different. Logogens and their verbal hierarchy are heavily sequentially constrained, whereas imagens and their nonverbal hierarchy are more holistic and simultaneous. This combination provides great flexibility to cognition.

Processing Operations

Three distinct dimensions, or “levels,” of processing are theorized in DCT: representational processing, associative processing, and referential processing. The levels metaphor is only partly useful because associative and referential processing can be seen as spreading activation at the same “level” but involving different codes. In DCT, processing involves both the degree and kind of elaboration.

Representational processing is the initial activation of logogens or imagens. This level is analogous to simply recognizing something as familiar and does not necessarily imply meaningful comprehension. The activation of a representation depends on the stimulus situation and individual differences. In reading text, the stimulus would be the text characteristics, and individual differences would include reading ability, background knowledge, instructions, and so on. Therefore, the activation of a visual logogen for a printed word would involve the legibility of the printed form, the reader's familiarity with the word's visual features and configuration, and any priming effects of context. If the visually recognized word was also familiar from speech, its associated auditory-motor phonological logogen usually would be activated rapidly in turn (e.g., *baseball*). All this would be carried out in milliseconds and perhaps without conscious attention. If the visual word was not familiar, visual and phonological logogens at lower levels such as letter combinations would be activated, requiring more time and attention (e.g., *base—ball)*. This may implicate higher-order processes in its recognition. On the other hand, whole familiar phrases can be recognized and named at a glance by the skilled reader (e.g., *baseball bat*).

Associative processing involves spreading activation within a code that is typically associated with meaningful comprehension. The association between a visual word logogen and an auditory-motor word logogen (i.e., phonological recoding) is an example of associative processing that does not necessarily involve meaning and is usually relegated to the representational level. However, the phonological recoding of a visual word may involve its comprehension in some cases. Heteronyms have one spelling but different meanings and respective pronunciations, and their phonological recoding depends on which meaning is implied by context (e.g., *bass* drum, largemouth *bass*). Unfamiliar and grapho-phonemically irregular words may implicate meaning as well because representational processing is slowed.

Meaningful associative processing within the verbal code involves the activation of logogens of at least the morpheme level by previously activated logogens. For example, the word *single* has many verbal associations, but only a subset will be activated in a given context. In a baseball game, the word *single* would activate verbal associations such as *hit, first base, advance a runner,* and so on. In other contexts, the word *single* could activate very different verbal associates such as *one-dollar bill, unmarried, hotel room,* and so on. Meaning is both constrained and elaborated by the set of verbal associates activated.

Referential processing involves spreading activation between the codes that is associated with meaningful comprehension. In reading, this means that activated logogens in turn activate imagens in the same way they activate other logogens. The phrase *baseball bat* can activate mental images of a wooden or aluminum baseball bat; and *single* can activate an entire dynamic, nested set of images of a batter hitting a baseball and running to first base in a stadium. That is, there is not a one-to-one referential correspondence between logogens and imagens. Some logogens might referentially activate few imagens, while other logogens might activate many. Some logogens might activate no imagens at all. This is particularly true of language that is highly abstract; it is difficult to form images of *basic idea*, for example. Without the context of a concrete situation, such phrases lack any referential meaning and can only be verbally defined. This implies that concrete language should be generally better understood, a consistent finding in research.

Once activated logogens spread their activation referentially to one or more imagens in the nonverbal system, associative processing may occur within that system and, in turn, refer back to the verbal system. For example, the set of imagens referentially activated by the logogen *single* might be associatively elaborated in the nonverbal system to include a batter running to first base in a crowded, cheering stadium. These imagens might in return referentially activate logogens such as *stadium* or *crowd* or *cheers*. In this way, spreading activation between and within codes defines and elaborates the meaning of language. Further, it supplies inferred information to the interpretation. Mental imagery plays an invaluable role in adding concrete sensory substance to the meaning; taken literally, this is what “making sense” in reading is all about.

Figure 1 shows a theoretical model of these units and processes. Verbal and nonverbal stimuli are perceived by the sensory systems and logogens and imagens are activated. The verbal system is illustrated as a hierarchical, sequenced arrangement of logogens. These units are modality-specific and of different sizes so that smaller ones may be representations for graphemes or phonemes, lager ones may be visual words or their auditory-motor pronunciations, and so on. The associative relationships illustrated by the arrows are of many kinds: grapho-phonemic associations (*b*-/*b*/), compound word associations (e.g., *base-ball*) common sequences (e.g., *first, second, third, home*), hierarchical associations (e.g., *organized activities, sports, baseball*), synonym or antonym associations (e.g., *batter-hitter; safe-out*), and on and on. The nonverbal system is illustrated as a series of overlapping and nested sets of imagens (e.g., a baseball bat being swung by a batter in a crowded, cheering stadium) or other imagens not associated with a given set. Referential connections are illustrated as arrows running between the coding systems. Verbal and nonverbal responses are shown as output of the respective systems.

This figure illustrates some of the most basic assumptions of DCT, but the illustration is necessarily simple. In actuality, a model for reading even a simple text would be interlaced with connections and abuzz with activity. Further discussion can be found in Sadoski & Paivio (2001).

Explaining the Reading Process

The discussion in the preceding section provided an overview of the basic assumptions of DCT in reading-relevant terms. The reading process can be better explained through an extended example that involves decoding, comprehension, and response in reading a simple sentence. We will deviate briefly to elaborate on decoding, comprehension, and response in turn. We use a single sentence here, but the reader should keep in mind that such sentences are more realistically read in much richer, extended contexts.

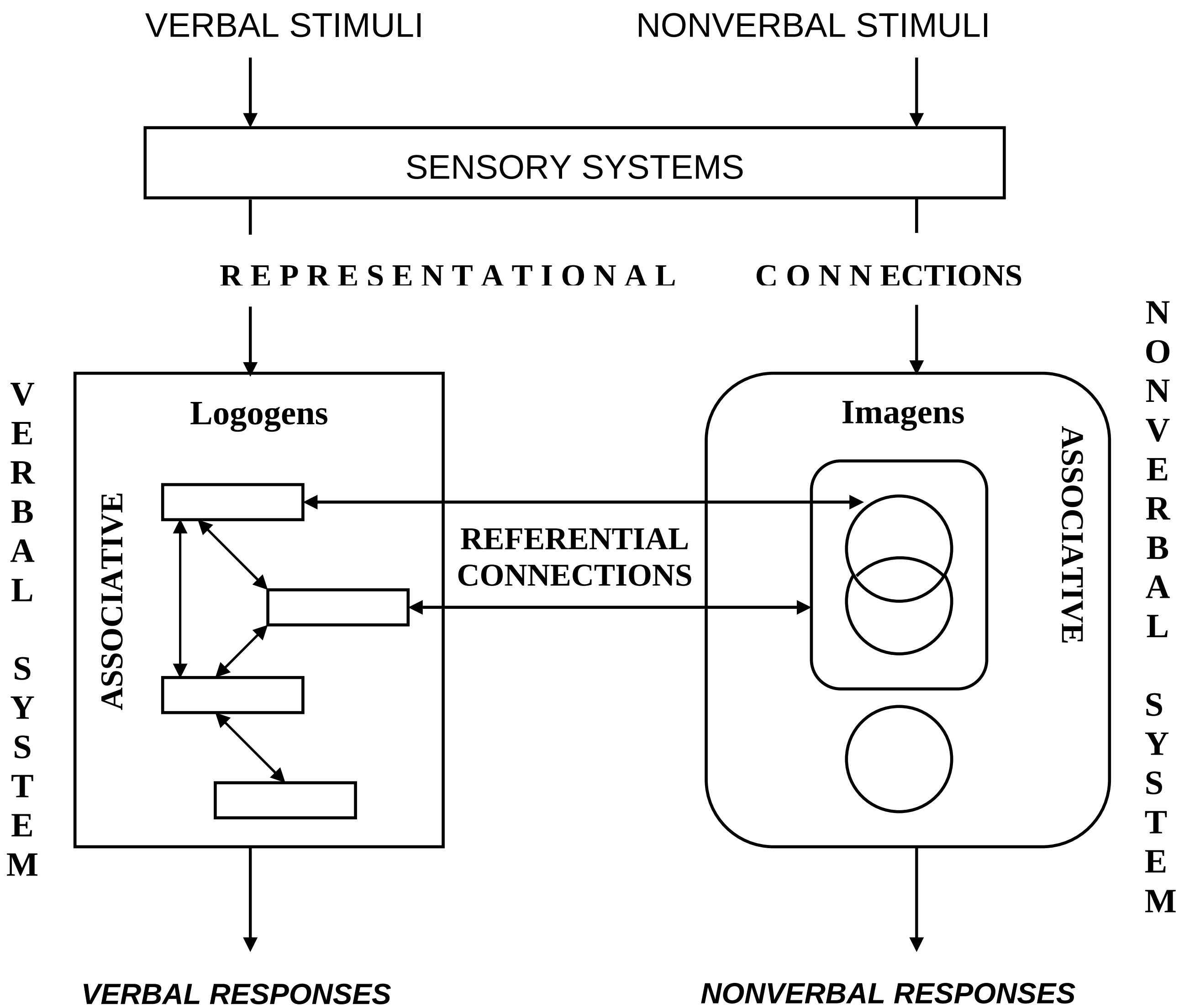

FIGURE 1
General Model of Dual Coding Theory

Consider the skilled reading and in-depth comprehension of the sentence *The batter singled to center in the first*. The process begins as the eyes fixate on the printed forms, probably *The batter* in the first fixation (eye movement studies indicate an average span of about nine characters per fixation). Visual logogens for the familiar words *The* and *batter* are activated at the representational level, and immediately associated with their auditory-motor logogens. “The batter” may be experienced as inner speech, recoded in phonological form. Perhaps equally quickly, the words are syntactically associated as a simple noun phrase. Spreading activation to semantic associations also occurs rapidly, with the different associates of *batter* activated as options. Common verbal associates of *batter* could be *baseball player* or *cake mixture* or *strike repeatedly*, and nonverbal referential connections could be images of the same. However, in the present context the word *batter* has been used in connection with other baseball terms, and context effects would prime the former option and inhibit the latter ones. Also, *The* preceding *batter* signals a noun usage of *batter*, syntactically inhibiting the verb option *strike repeatedly*. Within perhaps 500 milliseconds (an estimate from electroencephalographic studies), the words *The batter* are phonologically recoded and provisionally comprehended in both verbal and nonverbal form as a baseball player at bat.

A word here about decoding. In reading, this term is theoretically imprecise. The term *recoding* is often preferred because it indicates converting the printed form to the spoken form without necessarily comprehending, as the general definition of *decoding* implies (i.e., to decode a message). Conformably, DCT assumes that in reading, the activation of logogens at the representational level involves their phonological associations but not necessarily their semantic associates and referents. For highly familiar words this happens without conscious effort, hence the metaphor “automatic.” Very familiar phrases such as *The batter* may be activated as a single unit similar to *hot dog*. However, less familiar words, ambiguous words, or graphophonemically irregular words may require more grapheme-phoneme level processing, more conscious effort, and possibly some semantic and syntactic processing. Thus, DCT accommodates multiple-route models of phonology in word reading (e.g., Coltheart, Curtis, Atkins, & Haller, 1993).

Returning to our example, the next fixation falls on the word *singled*, perhaps already noticed in the parafovea of the first fixation. This word appears after the noun phrase and is marked as a verb by the *-ed* suffix. Associative processing syntactically connects *The batter* with *singled* and the familiar subject-verb syntactic pattern is recognized.

A word here about grammar: Extensive grammatical parsing is not often conscious, and it may be less complex than is commonly assumed. The verb here may be comprehended simply as a modifier of the noun phrase. That is, a mental model of the sentence thus far may be forming in which the batter is imagined in action, hitting the ball and running to first. This emerging mental model takes the form of a verbal-nonverbal, syntactic and semantic episode in short term memory. For those less familiar with baseball terms, the word *singled* may need to be syntactically paraphrased to *hit a single* for clarification, but the result would be the same. In this sense, grammar need not involve abstract, deep-structure propositions or transformational rules. Simple word sequences that evoke a comprehensible image can account for much. This is the DCT view of deep structure; more will be discussed later.

The next fixation includes *to center*. The various associates and referents of *to center* (e.g., *between left field and right field; to balance*) are part of the spreading activation, with context inhibiting less appropriate ones. Again, a less familiar reader may verbally elaborate this elliptical phrase into *to center field*. The words *The batter singled to center (field)* may then be syntactically parsed as the familiar subject-verb-modifier pattern, recoded phonologically as inner speech, and imagined to now include the ball speeding to the middle outfield as the batter runs to first base.

The final fixation falls on *in the first*. Familiar verbal elaborations of *in the first* such as *in the first inning* or *in the first place* may be associatively activated with context inhibiting the latter. The phrase will be recognized as a modifier by association with the syntax established so far and the entire sentence parsed and cumulatively recoded as inner speech. However, *in the first* would probably add little to the imaginal mental model of the episode except possible time cues such as the fresh uniforms and unscuffed baselines of the early innings of a baseball game. However, it might involve another nonverbal aspect of comprehension – an affective response. More on this presently.

As described so far, the processing of the simple sentence *The batter singled to center in the first* would take about two seconds at a typical reading rate of 250 wpm (longer for readers unfamiliar with baseball). For a skilled reader reading for full comprehension and recall, the result would probably include the sentence recoded as inner speech and comprehended as a verbal-nonverbal mental model of the episode. Note that neither is necessarily experienced consciously, or perhaps only barely so, and both may be rehearsed in memory after the last fixation. These responses differ with readers and situations. However, considerable experimental data including neuropsychological data support this scenario.

A few words here about meaning, comprehension, and mental models. As noted in the present example, the text would be mentally represented in two codes and in at least two different modalities: an auditory-motor representation probably experienced as inner speech, and a visuo-spatial representation probably experienced as mental imagery. Both might be elaborated in various ways. As noted, the word *center* may be mentally elaborated to *center field,* and *in the first* may be elaborated to *in the first inning.* Beyond this, verbal elaboration may take the form of a related set of activated associations in the verbal system such as *baseball, pitcher, swing, hit, fly, grounder, outfield, run, first base, safe, stadium, crowd,* and so on. The imagery representation might be in modalities other than the visual, depending on the degree of elaboration. A more fully elaborated image might include the crack of the bat and the roar of the crowd, for example. Associative connections and referential connections between the verbal associates and the nonverbal associates form an internally consistent network that is the basis of meaning, comprehension, and the mental model.

"Meaning" in this instance consists of this coherent network of activated verbal and nonverbal representations. The richer the elaboration of activated mental representations and their defining interconnections the more "meaningful" our response. "Comprehension" is the relative equilibrium in the network. The set of verbal associations and the set of nonverbal associations correspond and restrict each other sufficiently well to produce closure rather than a random-search activation without coherence. The term “mental model,” as used here, applies to the total verbal-nonverbal correspondence aggregate. The mental model *is* the restricted set of activated representations and the associative and referential connections between them. The term does not imply any theoretical construct beyond what has already been explained. A mental model in DCT is not an abstraction; the modality-specific units activated and connected retain some of their original sensory properties, much as pebbles in an aggregate or particles in a suspension.

However, the discussion of our example does not end here. Consider the inferences that may occur as a mental model is formed for the sentence *The batter singled to center in the first.* The sentence does not specify if the hit was a fly ball or a grounder. It does not specify if the game was a professional baseball game or a little league game. It does not specify if the stadium was opened or closed or if there was a stadium and spectators at all. It does not specify if the game was at night or during the day. Yet our mental models are often specific on such points. Many of these inferences can be attributed to mental imagery – imagining the general situation described by the language in concrete specifics. Imagery forms an invaluable companion to language in fleshing out its skeleton.

None of these inferences is obligatory; all are probabilistic in varying degree. Readers read with varying degrees of depth and elaboration based on purposes and individual differences. Comprehension is not an all-or-none process; it occurs in degrees from simple recognition to strategic elaboration. In many cases our comprehension is superficial because there is no time, need, or inclination to elaborate as deeply as we might. In other cases is our comprehension is deeper, richer, and more precise.

This leads us back to the subject of response. In many ways, this term implies the formation of a mental model, a coherent and elaborate rendition of the text. A reader may fully experience even a simple text such as *The batter singled to center in the first* by imagining the event as described. In a still more elaborate response, one might "feel" oneself as the batter, haptically sensing the heft of the bat and the jolt as it connects. But response often implies more than sensory imagery or a mental model. We noted earlier that the phrase *in the first* adds a time cue to the sentence. This simple time cue may evoke an evaluative and mildly affective response. A single *in the first* is not as critical as a *single in the bottom of the ninth with the game tied*. That is, there is a different emotional significance to the two time settings. This introduces a nonverbal, emotional-evaluative dimension to the response. In full and complete narrative texts such as stories, such emotional responses are an important aspect of experiencing the text (e.g., Sadoski, Goetz, & Kangiser, 1988).

In other contexts, response may take a more logical and rational form. Analyzing an exposition or an argument may introduce a verbal monitoring of the text experienced in inner expressions such as "I don't get this," or "Now I see," or "But you haven't considered…." Our critical and evaluative powers are also exercised here, and the experience may also be emotional. We are impressed with a well-argued position with which we are forced to agree. We are disappointed by sloganeering that dismisses a difficult problem with a one-syllable solution. In its fullest sense, response involves the reader as a part of the authoring, a partner who stands toe-to-toe with the author and answers back. This may take the reading beyond what the text language may have included or what the author may have ever intended.

A question sometimes raised of DCT is how we comprehend and respond to highly abstract language. The answer is that the encoding abstract language is primarily a matter of verbal associations. Consider the abstract sentence *The basic idea remained vague*. As with a more concrete sentence, this sentence can be phonologically recoded, grammatically parsed, and associated with other language units (e.g., *basic idea = main thought*, *remained vague = stayed unclear*). But beyond such mental parsing and paraphrasing, there is little substance to the sentence. Without a concrete contextual referent to concretize the abstract, it remains a verbalism with unrealized potential. Such sentences may be integrated as verbal units and achieve a degree of meaning at the associative level, but their fuller meaning and response awaits a more concrete context.

Empirical Evidence

The constellation of predictions derived from the DCT model of reading has only been partially developed and tested, but relevant evidence is available on several research fronts. We will next review certain empirical evidence in the areas of decoding, comprehension, and response.

Decoding

Printed words are usually recoded promptly into an auditory-motor (phonemic) form. In DCT, this involves activation of verbal-associative connections between visual logogens and auditory-motor logogens. As discussed above, these connections are generally assumed to occur at the representational level because they usually can be achieved before a syntactic or semantic interpretation is generated. However, this does involve associative processing, and the time required for this processing will presumably vary with word familiarity, grapheme-phoneme consistency, and other factors.

Therefore, spreading activation could theoretically reach and activate still other representations during this time. These representations include imagens, possibly implicating imagery as a semantic factor in word recognition.

In fact, word imageability is one of the best predictors of oral reading performance in beginning reading or in certain acquired disorders of reading. Beginning readers read concrete, imageable words more accurately than abstract words, with these effects more prominent for poor readers (Coltheart, Laxon, & Keating, 1988; Juel & Holmes, 1981; Jorm, 1977). Neurological patients with severe phonological deficits, whose reading ability is assumed to rely mainly on direct access from orthography to semantic interpretations, are often markedly more successful in reading concrete, imageable words than abstract words (e.g., Coltheart, Patterson, & Marshall, 1980; Funnell & Allport, 1987; Plaut & Shallice, 1993). This evidence is supportive of multiple-route models of the oral reading of words (cf. Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001).

If a word's concreteness can have any influence on the process of naming it, this influence might be seen mainly on words in which orthographic to phonological recoding is slowed by their low frequency and/or irregular spelling-sound correspondences. Strain, Patterson, and Seidenberg (1995) tested this prediction. They found that, controlling for word familiarity and linguistic variables (i.e., initial phoneme, word length, positional bigram frequency), adults were slower and more error prone when naming abstract irregular words (e.g., *scarce*) than when naming abstract regular words (e.g., *scribe*) or imageable irregular words (e.g., *sword*). That is, imageable words were named sooner and more accurately when they were irregular because the spelling-sound processing time was sufficient to allow for the activation of corresponding imagens. However, when the words were regular, the associations between spelling and sound rapidly achieved whether the words were concrete or abstract, so the activation of imagens for the concrete words did not produce a similar effect in naming. Overall, they found that imageability especially facilitated the naming of low-frequency irregular words.

This study has been subject to considerable replication and scrutiny. It was replicated and extended by Strain and Herdman (1999), who found the same interaction between frequency, regularity, and imageability in word naming. They also found an even stronger effect for imageability in the naming of low-frequency regular words, although this was still less than for low-frequency irregular words. They also found that the more skilled in decoding participants were, the less strongly imageability influenced word naming, although the effect was still present even for highly skilled decoders. Overall, they interpreted their findings to mean that imageability plays a role in naming words when the connections between orthography and phonology are weak, whether this is due to irregular spelling-sound correspondences or to low decoding skill.

Monaghan and Ellis (2002) replicated the original study and again found the interaction between regularity and imageability. However, they attributed it to age of acquisition of the word because when this variable was covaried the interaction was nonsignificant. They argued that irregular words and low frequency words would be acquired later and this would largely account for the effect. However, Strain, Patterson, & Siedenberg (2002) questioned the use of age of acquisition because when they reanalyzed their original data with age of acquisition as a covariate the interaction of regularity and imageability persisted. Furthermore, they presented new data confirming the interaction when age of acquisition was controlled. Ellis and Monaghan (2002) rejoined on methodological grounds but presented no new data. Overall, these results suggest a persistent but qualified interaction between imageability and regularity in word naming.

The theoretical point becomes clearer in different orthographies. Printed languages differ in the degree to which they represent spoken language. In Persian, words are sometimes written with consonant letters only (opaque words) and sometimes with full vowels (transparent words). The opaque words therefore present more decoding difficulties. A significant imageability effect was found by Baluch and Besner (2001) in naming both high and low frequency opaque words in Persian, while the effect was not present for matched transparent words. These findings have been extended to Turkish, a perfectly transparent orthography in which each of its 29 letters corresponds to only one spoken sound invariantly and independent of context. Raman, Baluch, and Besner (1997) found no significant effects of imageability on word naming of Turkish high and low frequency words, consistent with the prediction. However, Raman and Baluch (2001) additionally investigated reading skill and found that skilled readers in Turkish named imageable, low-frequency words faster than matched abstract low-frequency words, similar to what Strain and Herdman (1999) found in English and also consistent with prediction. Less skilled readers did not, a result different from Strain and Herdman, but this was attributed to differences in reading Turkish and English. Janyan and Andonova (2002) still found independent effects of imageability and frequency in naming words in Bulgarian, an orthography with more graphophonemic consistency than English but less than Turkish. Furthermore, these researchers found that imageability was more associated with right-hemispheric brain activation, consistent with a neuropsychological account of encoding differences.

In sum, these studies indicate that imageability plays a role in naming words when the connections between orthography and phonology are labored, whether this is due to irregular spelling-sound correspondences or low word frequency (i.e., unfamiliarity). The effect of decoding skill also interacts with these factors differently in different orthographies. These results are theoretically consistent with the interactive DCT model of reading presented above, as well as multiple-route decoding models. Specifically, visual logogens activated by printed concrete words spread their activation to both auditory-motor naming logogens and imagens for referential meaning. The activated imagens can significantly contribute to the activation of the naming logogens when the route between the visual logogens and the naming logogens is slow. The effect is predictably differential across orthographies, a script-specific phenomenon. The effect is also complex, predicting at least a triple interaction. As Strain et al. (2002, p. 212) concluded, “almost all of the factors in the domain of word familiarity and meaningfulness are correlated with one another, and it is a brave experimenter who attempts to establish the prominence of one while denying any impact for the others” (cf. Venezky & Massaro, 1987). Multiple factors influence word decoding of which imageability is one, under theoretically predictable conditions. These observations are compatible with DCT but incompatible with theories that posit modality-independent word units, concept nodes, or abstract propositions. Moreover, they have implications for sight vocabulary learning as discussed later.

Comprehension

In DCT, a key factor in reading comprehension is language concreteness. This is because concrete language can referentially activate mental images as well as associatively activate mental language, whereas abstract has relatively less access to the imagery code. Hence, concrete language such as *baseball bat* should be easier to understand than abstract language like *basic idea* – concrete language can be dually encoded. In DCT, the two codes are assumed to be independent and additive in their effects, predicting that concrete language should be nearly twice as comprehensible and memorable as abstract language, other factors being equal. The empirical record over the last 30 years has shown just this. Concrete words, phrases, sentences, paragraphs, and longer texts have been consistently shown to be more than twice as comprehensible and memorable as abstract language units matched for readability, familiarity, and other variables. The evidence relevant to reading has been extensively reviewed (Sadoski & Paivio, 2001). Here we will focus on how predictions made by DCT in the area of comprehension and recall have prevailed in experimental tests against the predictions of other theories.

A case in point involves the competing predictions of DCT and context availability theory (Kieras, 1978). Rather than assuming separate verbal and nonverbal codes, context availability theory assumes that all language, whether abstract or concrete, is comprehended and remembered by incorporation into a network of abstract, amodal propositions. Moreover, this theory assumes that concrete language is easier to comprehend and remember because it can be more readily associated with other propositions in the network – it simply has more connections. But this advantage can be offset when abstract language deals with highly familiar information or when abstract language is presented in a supportive context because the connections are then enhanced for the reader. The differing assumptions of DCT and the context availability model present a situation all too rare in reading research: two rival theories that are sufficiently well articulated to make testable predictions that are contradictory.

A test of these competing predictions was performed by Sadoski, Goetz, and Avila (1995). They used four factual paragraphs about historical figures (Michelangelo and James Madison) that were matched for number of sentences, words, and syllables, sentence length, information density, cohesion, and rated comprehensibility. In one set, two paragraphs were rated equal in familiarity but one paragraph was rated more concrete than the other. In this case, DCT predicted that the concrete paragraph should be recalled better than abstract paragraph due to the additional integrating medium provided by imagery, whereas the context availability model predicted that they should be recalled equally because the abstract language was equally familiar and presented in context. In the other set, the paragraphs differed in both familiarity and concreteness, with the abstract paragraph being the more familiar of the two. In this case, DCT predicted that the familiar abstract paragraph should be recalled about as well as the unfamiliar concrete paragraph (i.e., the advantage of concreteness would be offset by lower familiarity), whereas the context availability model predicted that the abstract paragraph would be recalled better than the concrete paragraph (i. e., the disadvantage of abstractness would be offset by higher familiarity).

In the case where the concrete and abstract paragraphs were equally familiar, study participants recalled the concrete paragraph nearly twice as well. In the case where the abstract paragraph was more familiar, study participants recalled the paragraphs equally well. These results were consistent with DCT but inconsistent with context availability theory. Other experimental findings using different methods and materials have confirmed these results (e.g., Holcomb, Kounios, Anderson, & West, 1999; Kounios & Holcomb, 1994; Nelson & Schreiber, 1992; Sadoski, Goetz, & Fritz, 1993; Sadoski, Goetz, & Rodriguez, (2000).

Another case of competing predictions between DCT and another theory involved the relational-distinctiveness model of Marschark and Hunt (1989) in explaining the integration of abstract text. Abstract sentences such as *The basic idea remained vague* can sometimes be encoded as integrated verbal units as well as concrete sentences, even though concrete sentences enjoy more comprehensible and memorable content. These questions about the DCT explanation of the integration and recall of abstract text were first raised by Marschark and Paivio (1977). They studied the cued recall of concrete and abstract sentences and found that, whereas recall was higher for concrete sentences, the two types of sentences did not differ in the extent to which recall was integrated as measured by the retrieval effectiveness of verbal cues that were related to the whole sentence or to only one content word in the sentence. The higher recall for concrete sentences was consistent with the DCT assumption that dually encoded information is more memorable, but the equal integration effect was inconsistent with the assumption that imagery is a superior integrating medium.

Marschark and Paivio (1977) concluded that dual coding accounted for the higher recall of concrete sentences, but some other explanation was needed to explain the equivalent integration effects. Verbal associative processes were a likely DCT candidate because these processes apply equally to concrete and abstract language. An alternative theory was posed by Marschark and Hunt (1989). This theory assumed that distinctiveness and relatedness are different forms of mental processing that acted as partners. Mental imagery evoked by concrete language increases the distinction or contrast of concrete language to abstract language rather than providing a separate memory code, but this distinctiveness is dependent on an established relationship between the language units. Hence, this theory, like context availability theory, predicts that familiar, contextually associated abstract language should be integrated as well as concrete language.

A resolution to the issue was obtained by Paivio, Walsh, and Bons (1994). Their experimental results showed that strong verbal associations are *necessary* to produce integration of abstract word pairs, whereas imagery is *sufficient* to produce integration of concrete word pairs even when verbal associations are not present. The results were not consistent with the relational-distinctiveness view because integration still occurred for concrete word pairs where the pair members were not related. These findings provide a DCT explanation for the integration of abstract language, but they further offer a possible explanation for the integration of even weakly related concrete language.

For example, consider again the abstract sentence *The basic idea remained vague* and the concrete sentence *The batter singled to center in the first*. The former sentence might be integrated grammatically because the predicate adjective *vague* links directly back to the subject noun *idea*; the modifier is part of the sentence kernel and binds the subject and the predicate closely together. In the latter sentence, the kernel is *The batter singled*; this is followed by two independent modifying phrases in a loose construction.

This sentence might be integrated more though its imagery, with *singled to center* and *in the first* adding imaginal and verbal elaboration as discussed previously. Stated differently, the integrative mental model of the abstract sentence may be more verbal-associative, and the integrative mental model of the concrete sentence may be more nonverbal-imaginal. Hence, both concrete and abstract sentences might be encoded as integrated units but for theoretically different reasons. However, this interpretation is speculative, and further research is needed on sentences.

In sum, DCT can provide a coherent account of the critical role played by language concreteness in reading comprehension. The evidence cited poses problems for theories that propose that all language is mentally encoded in abstract, propositional form. Furthermore, DCT can provide experimental predictions about the comprehension and recall of concrete and abstract text, and about the integration of both concrete and abstract text, in a theoretically consistent and parsimonious way.

Response

Mental imagery, and its correlate, emotional response, are vital to aesthetic response to text. Imaginative and affective processes are how a text is “realized” or “lived through” or “brought to life.” As discussed earlier, some aspects of response may be contemporaneous with the formation of a mental model of the text, so that the distinction between comprehension and response is somewhat fuzzy. Response can take more objective forms as well, such as critical evaluation against some standard as in rating the importance of a text segment relative to the whole.

The empirical evidence for the relationship between imaginative and affective processes in responding to text was reviewed by Goetz and Sadoski (1996). A program of research carried out over ten years revealed that imagery and affective response to text can be measured reliably and validly using conventional methods. Both the strength of response, as measured by quantitative ratings, and the nature of response, as measured by qualitative reports, were investigated in this research program.

The core of this research program was a set of complementary studies using literary short stories. In one study (Sadoski & Goetz, 1985), participants read and later rated each paragraph in an adventure story for either the degree of imagery experienced, the degree of emotional response experienced, or the relative importance to the story as a whole. The alpha reliabilities of these ratings, for this story as well as other similar stories, has been regularly found to exceed .90 (Sadoski et al., 1988; Goetz, Sadoski, Stowe, Fetsco, & Kemp, 1993). In all these studies, imagery ratings, affect ratings, and importance ratings were moderately to strongly correlated with each other in an overall response aggregate. The correlation between imagery ratings and affect ratings persisted even after controlling for paragraph length and the importance ratings. However, the relationship between either imagery ratings or affect ratings and importance ratings was considerably attenuated when the effects of paragraph length and the remaining rating were partialed. This means that imagery and affective response can generally be seen as a related but qualitatively different form of response from evaluating importance.

Qualitative reports were the focus of another related study (Sadoski, Goetz, Olivarez, Lee, & Roberts, 1990). Using the same story as Sadoski and Goetz (1985), participants read and then produced written recalls and imagery reports. Using the most extensive coding system for imagery reports yet devised, imagery was coded into categories such as (a) directly related to a paragraph, (b) a synthesis of information from two or more paragraphs, (c) distortion of story information, (d) an importation consistent with the story, or (e) an importation inconsistent with the story. The imagery reports were also categorized according to modality (e.g., visual, auditory, tactile, affective). Recall protocols were similarly coded in categories including (a) gist, (b) synthesis from across text units, (c) distortion, (d) an importation consistent with the story, or (e) an importation inconsistent with the story. Interrater reliability between independent raters ranged from .84 to .95 for all codings. A factor analysis of the imagery and recall categories revealed four underlying factors, dominated respectively by visual imagery, affective imagery (i.e., imagining the feelings of the characters), imported imagery consistent with the story, and distortion recall. Verbal recall categories loaded on these factors as well, but consistently lower. Hence, story response could be seen as primarily experienced in the form of mental imagery and affect and somewhat less in the form of verbal recall.

A subsequent study used the ratings from Sadoski and Goetz (1985) as predictors of the imagery reports of Sadoski et al. (1990). Goetz, Sadoski, & Olivarez (1991) employed hierarchical regression analyses that first removed between-subjects variance and variance due to surface level text factors and found that the paragraph level imagery ratings of the first group of readers were highly significant predictors of the respective paragraph level imagery reports of the second, independent group of readers. Another finding using the same methodology was that importance ratings and surface level text factors were better predictors of verbal recalls than of imagery ratings. Hence, the evaluation of importance can again be seen as qualitatively different from imaginative response, although they remain correlated in the overall response.

In sum, this program of research has shown that imaginative responses are central to reading literary stories, and that they can be defined, measured, and interpreted reliably and validly using conventional research methods. Imagery and emotional response are moderately to strongly correlated in story response. Further, they are both related to more objective, text-based responses such as evaluations of plot importance. As Sadoski et al. (1998, p. 333) noted, "… these three response types often occurred simultaneously, in what may be an overall response comprising both comprehension of plot salience, and vicarious, emotionally infused, and fully perceived experiences of story events." Together, they form an overall response that involves both the intellect and the emotions.

Comparison Between DCT and Other Theories of Reading

In an earlier section, we compared DCT with context availability theory and distinctiveness-relational processing theory in making predictions about reading. DCT also has been extensively compared with schema theory as an explanation of reading comprehension (Sadoski & Paivio, 1994; 2001; Sadoski, et al., 1991). DCT has also been extensively compared with the theories of Rumelhart (1977) and Kintsch (1988) in Sadoski and Paivio (2001). An updated version of Kintsch (1998) has also been addressed from a DCT perspective (Sadoski, 1999). We will summarize and comment on those comparisons here.

These theories of reading have much in common with DCT. A major similarity is that they are all interactive theories in which reading is served by bottom-up and top-down processes working in combination. All these theories are similar in assuming a prominent place for prior knowledge structures in reading. Another similarity is that they allow, to different degrees, for the representation of knowledge in more than one form.

However, a basic distinction between DCT and these other theories is that they assume that most knowledge in memory is abstract and amodal, existing in a state that is has no objective reality and is associated with no sensory modality. How any knowledge that is not innate becomes divorced from sensory input is an important theoretical and epistemological question that has not been well explained. These theories propose no apparent answer to this question; rather, they simply assume the existence of abstract, amodal knowledge. One apparent reason for this is so that these theories can be modeled by artificial intelligence and subjected to computer simulations.

Rumelhart's (1977) parallel distributed processing model is one example. The parallel sources of knowledge in this theory are letter-feature knowledge, letter knowledge, letter-cluster knowledge, lexical knowledge, syntactic knowledge, and semantic knowledge. The forms that these different knowledge sources take is not specified, but examples provided suggest that they are ultimately all in an identically computational form. For example, a series of equations is presented in Rumelhart (1977) that determines the Baysian probability of testing a set of multilevel hypotheses for the recognition and comprehension of a phrase against letter-feature data. Several computer programs are cited for the source of these formalisms including Kaplan's (1973) General Syntactic Parser and the HEARSAY speech recognition program (Lesser, Fennel, Erman, & Reddy, 1974). That is, whatever the source of the original input (e.g., visual features of letters), all information is theoretically converted to, and processed in, a common computational form. As a result, this theory does not discuss the roles of phonological recoding, inner speech, or mental imagery in any form. This would call for at least some differences in internal representation modalities. Rumelhart's (1977) model has since evolved into a connectionist theory that similarly assumes abstract, computational representations (cf. Rumelhart & McClelland, 1986).

Kintsch's (1998) construction-integration model is another example. This model assumes three codes or forms of knowledge representation: verbatim information, the propositional text base, and the mental model. Verbatim information is surface structure information including specific words and syntactic arrangements. The propositional code is an abstract, deep structure code formed when abstract proposition-schemata are instantiated with surface structure information and the surface structure is quickly lost. Individual propositions are then connected into a propositional text base. The mental model is either a well-integrated propositional text base or a mental image of a situation that is somehow derived from the text base. Hence, this theory can be seen as a triple-coding theory that assumes that verbal language and mental imagery may be inputs and outputs, but the central processing unit is propositional in nature. Hence, it is primarily a single-code theory (see Sadoski, 1999 for more discussion).

Recent modifications of this theory have made it still more amenable to computer programming. Rather than thinking of concepts or propositions as abstract nodes in a knowledge network, the theory now treats propositions as vectors of numbers in a multidimensional statistical space with each number indicating the strength with which the proposition is linked to another proposition (i.e., latent semantic analysis). This brings the theory closer to DCT on the one hand because associational strength between individual mental representations is critical, but farther away on the other hand because the entire system is based in computational formalism. As with Rumelhart (1977), this theory does not discuss the role of phonological recoding or inner speech, and it treats mental imagery as an afterthought.

Whether the formalisms of artificial intelligence as posed by these theories are useful in advancing our understanding of cognition in reading remains to be seen. Computer implemented models that coincide with human data are interesting exercises, but the name of the game in theory is to know why. Such exercises run the risk of reification – the fallacy of explaining something and then treating the explanation as real rather than the thing being explained. In any event, it is useful to remember that abstractions such as schemata, propositions, and abstract concept nodes are difficult to operationalize and empirically test with human data. Their interpretive power lies largely in the assumption that they exist in the first place, mentally analogous to computer programs. As an alternative, DCT relies on constructs that may be consciously experienced to some degree and for which plausible human assessments can be devised: natural language, mental imagery, and their associations.

Directions for Further Research

Although it is one of the better established theories of general cognition, DCT is a relative newcomer to the scene of reading theory. Despite a strong empirical record over the last several decades in accounting for verbal behavior, much more research is needed. In this section, we will pose certain issues deserving of further research in decoding, comprehension, and response.

Decoding

There is now considerable evidence that the concreteness or imageability of written language is a factor in its phonological recoding. This is consistent with the interactive nature of reading, where top-down semantic and syntactic factors and bottom-up decoding factors interact at all levels. This also reinforces the assertion that there may be more to the phenomena of phonological recoding and inner speech than providing us with a strategy for lexical access – meaning may precede phonology more than we realize. While much phonological recoding may occur at a deep, cortical level, its more conscious manifestation is inner speech.

Despite the pervasiveness of inner speech in reading, too little is known about this phenomenon. Huey (1908) devoted a chapter to it, regarding inner speech as a ubiquitous short-term memory phenomenon. In a landmark study in which subvocalization was measured by surgically inserting electrodes into the speech musculature, Edfeldt (1960) found that: (a) all readers appear to engage in inner speech to varying degrees, especially as reading becomes increasingly difficult, (b) inner speech has no detrimental effect on reading, and (c) good readers engage in less inner speech than poor readers. Both Huey and Edfeldt pointed out that inner speech was not inevitable in reading. Later research reviews by Gibson and Levin (1975) and Rayner and Pollatsek (1989) arrived at the same general conclusions: Inner speech seems to be a useful but not obligatory vehicle for recoding text in short-term memory in order to parse sentences, associate words contextually, and inwardly express a spoken interpretation.

But these explanations raise unanswered questions. If inner speech is not strictly necessary, why not simply an "inner semantics" that operates directly on print input, at least for good readers past the early developmental stages of reading? Speed reading courses have long advocated “breaking the sound barrier” and reading purely visually to increase rate and improve comprehension and retention (Frank, 1994). However, Carver (1982) empirically determined that for skilled readers the optimal rate of comprehending prose while reading was identical to the optimal rate of comprehending prose while listening. This rate was about 300 words per minute – about the maximum rate at which speech can be comfortably produced. What accounts for the pervasiveness of inner speech, its increase as text difficulty increases, and its convergence with rate of comprehension, if it is unnecessary?

The DCT approach to these issues might pose inner speech as mental imagery in the auditory-motor modality being used to retain the surface form of a sentence while higher-order comprehension processes occur. Recoding printed language from the visual modality to auditory-motor form is needed because the visual modality can be overloaded if it has to simultaneously: (a) hold sentence segments already seen in visual memory, (b) process upcoming print, and (c) construct visual mental images as needed or preferred. Earlier in the paper we discussed the concept of modality-specific interference, the difficulty of trying to perform different tasks in the same sensory modality. The principle may apply strongly here: There is too much activity in reading for the visual pathways in the brain to handle alone. Recoding to the auditory-motor modality allows non-visual rehearsal and speech-like parsing to occur while new text is visually processed and a semantic interpretation, including visual images, is constructed. Of course, inner speech may serve other functions as well, such as strategically “sounding out” unfamiliar words or “hearing” vocal phrasings, intonations or other forms of expressive interpretation. It may also serve as an internal surrogate for the original and most common form of comprehended language, oral speech.

In short, inner speech may serve a needed rehearsal function in an alternative modality without which reading could not optimally occur. Educationally, this implies that inner speech should be encouraged and taught when in fact many instructional programs have been introduced to eliminate it. Theoretically, this implies still more problems for propositional theories. If the surface form of the text is immediately converted to abstract, amodal propositions and the surface structure lost, what theoretical purpose could inner speech possibly serve and why should it be so common?

Comprehension

An issue in need of renewed research from the point of view of all cognitive theories is that of the nature of grammar and its role in comprehending text. Over the ages, grammars of various kinds have been formulated including traditional grammar, structural grammar, case grammar, and transformational grammar. The similarities and differences between these grammars is more complex than is usually assumed. Chomsky's (1957) transformational grammar, which shared much with traditional grammar and was contrasted with the descriptive patterns of structural grammar, enjoyed considerable popularity during the second half of the twentieth century. However, its explanation of sentence comprehension has become heavily strained and has not met with empirical support.

According to the transformational view, all mental activity is rule-governed and verbal. Complex sentences are mentally broken down into their deep-structure kernels and understood in terms of transformational rules that are basically innate and universal.

Therefore, sentence comprehension is a function of transformational complexity, or the number and nature of transformations that separate a sentence from its underlying structure. However, empirical research has found that after controlling for sentence length and implied changes in meaning, transformations had little effect on processing time (reviewed in Williams, 1998). That is, neither deep structures nor transformations appeared to have any psychological reality. However, studies of sentence transformation consistently showed that word meaning plays a crucial role in comprehension, even overriding syntactic information at times (reviewed in Paivio, 1971). Paivio suggested that imagery may play a substantial role in sentence grammar, particularly in the case of concrete sentences.

Semantic word attributes invited attention to case grammars. These grammars described sentences as relationships between cases such as agent, object, instrument, and so on (e.g., Fillmore, 1968). Early versions of these grammars, modified by developments in artificial intelligence and by some psychological evidence, were used as the basis of various propositional approaches to cognition and language (e.g., Kintsch, 1998). However, Fillmore (1977, 1984) revised his case grammar theory by putting special emphasis on the perceptual, or imagined, scenes and perspectives to which sentences refer. Case grammar with these modifications met with more empirical support than transformational grammar. For example, Black, Turner, and Bower (1979) had subjects read sentences with a single vantage point such as *Terry finished working in the yard and went into the house* and sentences with a changing vantage point such as *Terry finished working in the yard and came into the house*. Sentences with changing vantage points took longer to comprehend, were rated harder to understand, and were likely to be recalled from a single vantage point. Such evidence provides more support for the view that both verbal and nonverbal processes are involved in grammar and comprehension.

More recent developments are still more consistent with the DCT view. Connectionist views have produced a form of grammar called *cognitive grammar* (Langacker, 1987, 1990). Cognitive grammar simplifies the field by rejecting the rule-governed model of mind and language and replacing it with an associational model. In this model, networks of association evolve with the experience of the individual including linguistic associations. No innate or intrinsic rules are involved; language is governed by patterns of regularity that develop from childhood. The number of common syntactic patterns in a language is relatively small (e.g., the subject-verb-object pattern in English). All sentences are variations on a few patterns that may be represented as exemplars and varied by analogy. Descriptive, structural grammar is best suited to this explanation of grammar, and word meaning plays a more important role.

More significantly from the DCT point of view, cognition is not seen as essentially verbal. Cognitive grammar assumes that mental representations can be imagistic. Language processing is a matter of matching words with mental representations and mental models of reality that may be in the form of imagery. Imagery is therefore an important substratum of language in the form of experience-based knowledge of the world to which language refers, rather than a propositional deep structure with innate origins.

In sum, cognitive grammar offers an elegant, empirically verifiable approach that capitalizes on verbal and nonverbal mental representations and syntactic patterns that are readily experienced and do not require the burdensome and unverified assumptions of transformational grammar. The consistency of DCT with these explanations is strong, and future research in this area great holds promise for understanding the nature and role of grammar in reading.

Response

Considerable progress has been made in linking theories of literary interpretation to scientific theories of cognition with empirical verification, a situation little entertained as recently as twenty-five years ago (Kruez & MacNealy, 1996). Indeed, the study of reader response to literature has become one of the more popular subjects in reading research. Mental imagery and affect are obviously crucial to literary response because the sensuous realization of setting, episode, character, and conflict is central to the "lived through" experience of a literary text. If evidence is needed to support this point, Miall and Kuiken (1995) factor analyzed a questionnaire of 68 items covering a broad spectrum of literary responses and found factors for imagery and empathy. They grouped these into a higher-order factor they called *experiencing*, the dimension of being absorbed in a literary work. Conformably, much research from the DCT perspective has shown that imagery and emotional response are persistently related in responding to literature. This research was reviewed by Goetz and Sadoski (1996) and was summarized earlier.

An issue that deserves attention is the challenge posed by this research for some reader-response theories. Rosenblatt's (1994) transactional theory has enjoyed considerable attention in recent years as an explanation for the way readers approach texts with different stances in mind. Specifically, this theory proposes that the reading transaction exists on a continuum between efferent reading and aesthetic reading. In the efferent stance, the reader is mainly concerned with information to be extracted and retained after the reading event. In the aesthetic stance, the reader is mainly concerned with the evocation of sensations, images, and scenes as they unfold in the moment. The reader may vary stances so that, for example, poetry could be read as a source of historical information, or an historical exposition could be read to imagine the sights, sounds, and emotions of the historical events. Moreover, readers can slide along the continuum from moment to moment within a reading, so that no reading is probably ever purely efferent or aesthetic.

The challenge involved is that considerable evidence exists to show that what is most imaged and felt in a reading is what is most retained over the long term. For example, Sadoski and Quast (1990) had their participants read and then rate the paragraphs in three feature journalism stories for the imagery experienced, the emotions experienced, or the importance to the story as a whole. Readers were assigned to read the articles as they would normally read an article about current events and people, not for testing. Sixteen days later, the readers were given a surprise recall task: They were asked to write down whatever they most remembered about the stories. What was recalled was overwhelmingly associated with the emotions and imagery experienced during the reading as determined by their own statements and earlier ratings. What was rated as important was recalled poorly. That is, what was retained long after the reading event was the subjective, aesthetic experience.

This seems inconsistent with the postulation of an efferent-aesthetic continuum. If this continuum works as a true continuum, it follows that as the reader moves toward one pole, he or she must move away from the other. If efferent reading is determined by what is retained, than the aesthetic aspects of the reading, including images and emotions, should have been poorly recalled, and information seen as important should have been better recalled. But these results indicate that what was carried away from the reading was aesthetic. That is, the transactional theory of reader response does not appear to sufficiently take into account the nature of memory for what is read whatever the reader's stance may be. We do not necessarily remember what we read for information unless we make efforts to memorize or otherwise record the information. Mental imagery and its frequent correlate, emotional response, can be evoked even when reading for superficial information. For example, Sadoski et al. (1990) found that students who were assigned to read to find typographical errors intentionally inserted in the text of a literary story reported as much imagery and affect as students assigned to read the story normally for pleasure. In short, stance may be less consequential than is assumed; a good story is captivating even if we intend to read for other purposes.

Directions for Practice

DCT provides rich implications for instruction in decoding, comprehension, and response. A growing body of empirical support for DCT principles in each of these areas of teaching reading has been identified and synthesized, and more research is forthcoming. We will briefly review highlights.

Decoding

Recently, decodable texts have been extensively used in beginning reading. Decodable texts use a high proportion of graphophonemically regular words that are intended to assist students in learning to decode and gain a sight vocabulary. However, word imageability has also been found to strongly affect sight word learning. That is, decodability may not be enough.

Hargis and Gickling (1978) taught kindergartners a set of concrete sight words and a set of abstract sight words that were matched for length and frequency. All the words were familiar words that were initially unknown to the children by sight. During training, the children: (a) were shown the words on flash cards, (b) heard each word pronounced, (c) heard each word used in a sentence, (d) used the word in a sentence of their own, and (e) repeated the word. Two days later, more than three times as many concrete words were correctly named. Ten days later, more than four times as many concrete words were correctly named. These results were later replicated with both kindergartners of normal ability and older mentally retarded children (Gickling, Hargis, & Alexander, 1981).

Kolker & Terwilliger (1981) also taught first-and second-grade children concrete and abstract sight words. The words were initially unknown by sight but were familiar in speech. The words were presented for one second on a flash card and pronounced for the child. The child then repeated the words and corrections were provided as necessary. This continued until a learning criterion was reached. The first graders took about 60% more trials to learn to correctly name the abstract words than the concrete words. The difference for the second graders was less (about 8% more trials for abstract words) but still statistically significant. Terwilliger and Kolker (1982) replicated their results while manipulating word confusability (i. e., same or different initial consonants). Similar results were obtained with kindergartners and beginning first graders by van der Veur (1975) and Wolpert (1972).

Hargis, Terhaar-Yonkers, Williams, and Reed (1988) extended this research to middle-grade children with reading problems. Besides manipulating word concreteness, the experiment included manipulations for word decodability and word presentation in story context or in isolation. Results determined that: (a) concrete words were learned about 12% faster than abstract words, (b) words presented in story contexts were learned about 12% faster than words presented in isolation, and (c) decodable words were learned about 6% faster than nondecodable words. An interaction between these factors indicated that abstract words presented in isolation took the longest to learn regardless of decodability, whereas concrete, decodable words were learned fastest regardless of context.

The results of these studies are very consistent with DCT and suggest that beginning reading materials and lessons emphasize concreteness as well as decodability and context in learning sight vocabulary. Overall, concrete words are learned faster even without the benefit of context, especially if decodable. Abstract words that vary in decodability are learned more slowly and benefit more from being learned in context. These results are compatible with similar findings with word recognition by adults as discussed earlier (e.g., Strain et al., 1995, 2002; Strain & Herdman, 1999).

Comprehension

DCT principles have been extensively applied to teaching reading comprehension throughout history, often intuitively. Sadoski and Paivio (2001) reviewed the history of teaching text comprehension from ancient times to modern and found an alternation between emphasis on the abstract and the verbal (e.g., outlines, epitomes) and the concrete and the imaginal (e.g., object lessons, imagery training). Clark and Paivio

(1991) reviewed decades of empirical studies relevant to DCT in education and determined that mental imagery, concreteness, and verbal associative processes play major roles in the representation and comprehension of knowledge, learning and memory of school material, effective instruction, individual differences, and motivation. Ruddell (1997), in his summary of his research program on influential teachers of reading, found that such teachers used highly effective strategies including the use of concrete examples, their extension to more abstract examples, and the analysis of abstract concepts in concrete terms.

The use of induced mental imagery to enhance student understanding and learning has gained an increasing record of acceptance (see reviews by Gambrell & Koskinen, 2002; Sadoski & Paivio 2001). The general conclusion of both of these reviews is that instructions to form mental images significantly enhances the reading comprehension and memory of both children and adults in various ways. Numerous studies have shown, for example, that elementary-age students know how to induce mental imagery and that only brief training and teacher scaffolding is necessary for most children to effectively use mental imagery as a reading comprehension strategy.

For example, Gambrell (1982) had first and third graders read short stories in sections. Before each section, the experimental group was told to make pictures in their heads to help remember, whereas the control group was told to think about what they read in order to remember. After reading each section, the participants were asked a prediction question, "What do you think is going to happen next?" Their responses were scored for factual accuracy and number of accurate predictions. Third graders in the imagery group reported twice as many facts and made twice as many accurate predictions as controls. First grades in the imagery group also tended to outperform controls on both measures, but the differences were not statistically significant. This study indicates that even with minimal inducement, children can use mental imagery comprehend factual material and make accurate inferential predictions.

Mental imagery has also been used as a remediation technique for poor comprehenders. One example is a technique developed by Bell (1986) that is based on DCT principles. Instruction involves requiring students to image in increasing detail to progressively larger units of language including words, phrases, sentences, and texts. This technique was experimentally tested against reciprocal teaching as a comprehension development strategy (clarify, summarize, question, and predict) and a no-strategy control condition (Johnson-Glenberg, 2000). A variety of comprehension measures was used including prediction, recall, explicit questions, implicit questions, and a standardized reading comprehension test. While many of the between-group contrasts did not significantly differ, both experimental treatments outperformed the control condition on answering implicit questions. The reciprocal teaching group outperformed the imagery training group only on answering explicit questions. The researcher concluded that both forms of strategy training were generally valuable in improving the comprehension of students with problems in this area. Further research in this area would be useful.

Response

Teaching reader response is an area fraught with controversy. Miall (1996) based on his extensive research into reader response, questioned whether response can or should be taught at all. He bemoaned the status of teaching literary response in many classrooms:

> I am aware of literature classes in schools and universities that, although often well-intentioned, are laying waste to students' experiences of literature. Like the loggers in one of our northern forests, there are teachers in too many classes whose work succeeds only in clear cutting every shoot of literary interest, leaving hardly a stump behind, mainly for the sake of that giant pulp mill, the testing and examining of students (Miall, 1996, pp. 463-464).

There is no easy solution to this problem. Images and feelings are deeply personal, and instruction in *what* to imagine and feel is surely less appropriate *than* to imagine and feel. The basis of an effective literary education is in nurturing response, but also in disciplining it so that it is not simply a flight of the imagination or an exercise in the affective fallacy. Finding a way to do this is a pressing problem for researchers and educators. One educationally valid method from a reading point of view might involve the avoidance of didactically explaining the effects of a literary work, and instead investigating how authors get whatever effects they get in readers.

Sadoski (2002) discussed how DCT principles might explain the way poets use imagery and language in collaboration or contention to obtain effects on readers. Several commonly taught poems are presented, showing that the mental images evoked by the poem are sometimes in contrast with the language of the poem. For example, John Masefield's poem "Sea Fever" deals with a sailor's yearning to go back to sea, although the reasons for not doing so are unclear. Images are evoked of tall sailing ships, the kick of the wheel, the song of the wind, and the clouds flying by. But the rhythm of the poem alternates between rollicking, fast-paced lines and slower, languorous lines. The images are all of freedom, but the lines constrain the reader every time the poem gets going again. The language therefore is inconsistent with the images evoked, and the contrast is provocative. Does this mean that the sailor is somehow incapacitated and either spiritually or physically unable to go back to sea? No explicit meaning can be assigned because it is all inferred and ambiguous. Rather, the effects obtained in the readers are discussed in a disciplined way without acceptance or rejection. This approach may be more appropriate for some poems than others, but as a general approach, the scrutiny of the effects produced by language and imagery in collaboration or in contrast may be one useful solution to how to best deal with reader response in education.

Conclusion

DCT is a theory of general cognition that addresses reading in all its psychological aspects. Few theories offer this scope and have achieved its broad base of empirical support. Comprehensive cognitive theories of reading with established programs of scientific testing are young, little more than thirty years old. They may be compared to the first comprehensive theory of gravitation that dates back over three hundred years or to the first comprehensive theory of evolution that dates back nearly one hundred and fifty years. New theories are subject to change as evidence accumulates, and they can be expected to make few clear and unambiguous predictions (a statement that applies to all the theories in this volume). However, DCT specifies to a considerable extent constructs of mind that have been of interest since ancient times and will undoubtedly continue to be of interest in the future. Both language and mental imagery in its various forms are among these constructs. The predictions of DCT have held up favorably against other theories to date and its future in advancing knowledge of reading is promising.

References

Baluch, B., & Besner, D. (2001). Basic processes in reading: Semantics affects speeded naming of high-frequency words in an alphabetic script. *Canadian Journal of Experimental Psychology, 55,* 63-69.

Bell, N. (1986). *Visualizing and verbalizing for language comprehension and thinking.* Paso Robles, CA: Academy of Reading Publications.

Black, J. B., Turner, T. J., & Bower, G. H. (1979). Spatial reference points in language comprehension. *Journal of Verbal Learning and Verbal Behavior, 18*, 187-198.

Carver, R. P. (1982). Optimal rate of reading prose. *Reading Research Quarterly, 18,* 56- 88.

Chomsky, N. (1957). *Syntactic structures*. The Hague, Netherlands: Mouton.

Clark, J. M., & Paivio, A. (1991). Dual coding theory and education. *Educational Psychology Review, 3,* 149-210.

Coltheart, M., Curtis, B., Atkins, P., & Haller, M. (1993). Models of reading aloud: Dual-route and parallel-distributed-processing approaches. *Psychological Review, 100,* 589-608.

Coltheart, M., Laxton, V. J., & Keating, C. (1988). Effects of word imageability and age of acquisition on children's reading. *British Journal of Psychology, 79*, 1-12.

Coltheart, M., Patterson, E. K., & Marshall, J. C. (Eds.) (1980). *Deep dyslexia*. London: Routledge & Kegan Paul.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review, 108*, 204-256.

Denis, M. (1982). Imaging while reading text: A study of individual differences. *Memory & Cognition, 10,* 540-545.

Eddy, J. K., & Glass, A. L. (1981). Reading and listening to high and low imagery sentences. *Journal of Verbal Learning and Verbal Behavior, 20,* 333-345.

Edfeldt, A. W. (1960). *Silent speech and silent reading.* Chicago, IL: University of Chicago Press.

Ellis, A. W., & Monoghan, J. (2002). Reply to Strain, Patterson, and Seidenberg, (2002). *Journal of Experimental Psychology: Learning, Memory, & Cognition, 28*, 215-220.

Fillmore, C. J. (1968). The case for case. In E. Bach & R. T. Harms (Eds.), *Universals in linguistic theory* (pp. 1-88). New York: Holt Rinehart & Winston.

Fillmore, C. J. (1977). The case for case reopened. In P. Cole & J. M. Sadock (Eds.), *Syntax and semantics (vol. 8) Grammatical relations* (pp. 59-81). New York: Academic Press.

Fillmore, C. J. (1984). Lexical semantics and text semantics. In J. E. Copeland (Ed.), *New directions in linguistics and semiotics* (pp. 123-147). Houston, TX: Rice University Studies.

Frank, S. D. (1994). *The Evelyn Wood seven-day speed reading and learning program.* New York: Barnes & Noble Books.

Funnell, E., & Allport, A. (1987). Non-linguistic cognition and word meanings: Neuropsychological exploration of common mechanisms. In A. Allport, D. MacKay, W. Prinz, & E. Scheerer (Eds.), *Language perception and production: Relationships between listening, speaking, reading, and writing* (pp. 367-400). New York: Academic Press.

Gambrell, L. B. (1982). Induced mental imagery and the text prediction performance of first and third graders. In J. A. Niles & L. A. Harris (Eds.), *New inquiries in reading research and instruction* (pp. 131-135). Thirty-first Yearbook of the National Reading Conference. Rochester, NY: National Reading Conference.

Gambrell, L., & Koskinen, P. S. (2002). Imagery: A strategy for enhancing comprehension. In C. B. Block & M. Pressley (Eds.). *Comprehension instruction: Research-based best practices*. New York: Guilford Publications.

Goetz, E. T., & Sadoski, M. (1996). Imaginative processes in literary comprehension. In R. J. Kreuz & M. S. MacNealy (Eds.) *Empirical approaches to Literature and aesthetics* (pp. 221-240). Norwood, NJ: Ablex.

Goetz, E. T., Sadoski, M., & Olivarez, A., Jr. (1991). Getting a reading on reader response: Relationships between imagery, affect, and importance ratings, recall and imagery reports. *Reading Psychology, 12,* 13-26.

Goetz, E. T., Sadoski, M., Stowe, M. L., Fetsco, T. G., & Kemp, S. G. (1993). Imagery and emotional response in reading literary text. *Poetics, 22,* 35-49.

Gibson, E. J., & Levin, H. (1975). *The psychology of reading*. Cambridge, MA: MIT Press.

Gickling, E. E., Hargis, C. H., & Alexander, D. R. (1981). The function of imagery in sight word recognition among retarded and nonretarded children. *Education and Training of the Mentally Retarded, 16,* 259-263.

Hargis, C. H., & Gickling, E. E. (1978). The function of imagery in word recognition development. *Reading Teacher, 31*, 870-874.

Hargis, C. H., Terhaar-Yonkers, M., Williams, P. C., & Reed, M. T. (1988). Repetition requirements for word recognition. *Journal of Reading, 31,* 320-327.

Hodges, C. L. (1994). The role of visual mental imagery in the speed-accuracy tradeoff: A preliminary investigation. *Journal of Educational Technology Systems, 23,* 53-61.

Holcomb, P. J., Kounios, J., Anderson, J. E., & West, W. C. (1999). Dual-coding, context-availability, and concreteness effects in sentence comprehension: An electrophysiological investigation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25,* 721-742.

Huey, E. B. (1908). *The psychology and pedagogy of reading.* New York: Macmillan. (Reprinted 1968, Cambridge, MA: MIT Press).

Janyan, A., & Andonova, E. (2002). Hemispheric differences in a word naming task. Paper Presented at the First International Conference on Literacies. Evora, Portugal.

Johnson-Glenberg, M. C. (2000). Training reading comprehension in adequate decoders/poor comprehenders: Verbal versus visual strategies. *Journal of Educational Psychology, 92,* 772-782.

Jorm, A. F. (1977). Effect of word imagery on reading performance as a function of reader ability. *Journal of Educational Psychology, 69,* 46-64.

Juel, C., & Holmes, B. (1991). Oral and silent reading of sentences. *Reading Research Quarterly, 16*, 545-568.

Kaplan, R. M. (1973). A general syntactic processor. In R. Rustin (Ed.), *Natural language processing*. New York: Alogrithmics.

Kieras, D. (1978). Beyond pictures and words: Alternative information-processing models for imagery effects in verbal memory. *Psychological Bulletin, 85*, 532-554.

Kintsch, W. (1988). The role of knowledge in discourse comprehension: A construction-integration model. *Psychological Review, 95*, 163-182.

Kintsch, W. (1998). *Comprehension: A paradigm for cognition*. Cambridge, UK: Cambridge University Press.

Kolker, B., & Terwilliger, P. N. (1981). Sight vocabulary learning of first and second graders. *Reading World, 20*, 251-258.

Kounios, J., & Holcomb, P. J. (1994). Concreteness effects in semantic processing: ERP evidence supporting dual-coding theory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*, 804-823.

Kreuz, R. J., & MacNealy, M. S. (Eds.) (1996). *Empirical approaches to Literature and aesthetics*. Norwood, NJ: Ablex.

Langacker, R. (1987). *Foundations of cognitive grammar: Vol. I. Theoretical prerequisites.* Stanford, CA: Stanford University Press.

Langacker, R. (1990). *Concept, image, and symbol: The cognitive basis of grammar.* New York: du Gruyter.

Lesser, V. R., Fennell, R. D., Erman, L. D., & Reddy, D. R. (1974). *Organization of the HEARSAY II speech understanding system* (Working Papers in Speech Recognition III). Pittsburg, PA: Carnegie-Mellon University, 11-21.

Liberman, A. M., & Mattingly, I. G. (1985). The motor theory of speech perception revisited. *Cognition, 21,* 1-36.

Marschark, M., & Hunt, R. R. (1989). A reexamination of the role of imagery in learning and memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 710-720.

Marschark, M., & Paivio, A. (1977). Integrative processing of concrete and abstract sentences. *Journal of Verbal Learning and Verbal Behavior, 16*, 217-231.

Miall, D. (1996). Empowering the reader: Literary response and classroom learning. In R. J. Kreuz & M. S. MacNealy (Eds.) *Empirical approaches to Literature and aesthetics* (pp. 463-478). Norwood, NJ: Ablex.

Miall, D. S., & Kuiken, D. (1995). Aspects of literary response: A new questionnaire. *Research in the Teaching of English*, *29,* 37-58.

Monaghan, J., & Ellis, A. W. (2002). What exactly interacts with spelling-sound consistency in word naming? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*, 183-206.

Nelson, D. L., & Schreiber, T. A. (1992). Word concreteness and word structure as independent determinants of recall. *Journal of Memory and Language, 31,* 237-260.

Paivio, A. (1971). *Imagery and verbal processes*. New York: Holt, Rinehart, and Winston. (Reprinted 1979, Hillsdale, NJ: Lawrence Erlbaum Associates)

Paivio, A. (1986). *Mental representations: A dual coding approach*. New York: Oxford University Press.

Paivio, A. (1991). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology, 45,* 255-287.

Paivio, A., Walsh, M., & Bons, T. (1994). Concreteness effects in memory: When and why? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 1196-1204.

Plaut, D. C., & Shallice, T. (1993). Deep dyslexia: A case study of connectionist neuropsychology. *Cognitive Neuropsychology, 10,* 377-500.

Raman, I., & Baluch, B. (2001). Semantic effects as a function of reading skill in word naming of a transparent orthography. *Reading and Writing, 14*, 599-614.

Raman, I., Baluch, B., & Besner, D. (1997). Imageability and frequency effects on visual word recognition: Evidence from a transparent orthography. Paper presented at the Fifth European Congress of Psychology, Dublin, Ireland.

Rayner, K., & Pollatsek, A. (1989). *The psychology of reading*. Englewood Cliffs, NJ: Prentice-Hall.

Rosenblatt, L. M. (1994). The transactional theory of reading and writing. In R. B. Ruddell, M. R. Ruddell, & H. Singer (Eds.), *Theoretical models and processes of reading* (4th ed.) (pp. 1057-1092). Newark, DE: International Reading Association.

Ruddell, R. B. (1997). Researching the influential literacy teacher: Characteristics, beliefs, strategies, and new research directions. In C. K. Kinzer, K. A.

Hinchman, & D. J. Leu (Eds.), *Inquiries in literacy theory and practice* (pp. 37-53). Chicago, IL: National Reading Conference.

Rumelhart, D. E. (1977). Toward an interactive model of reading. In S. Dornic (Ed.), *Attention and performance VI* (pp. 573-603). New York: Academic Press.

Sacks, O. (2002, October 7). The case of Anna H. *The New Yorker*, pp. 62-73.

Rumelhart, D. E., & McClelland, J. L. (1986). *Parallel distributed processing.* Camdridge, MA: MIT Press.

Sadoski, M. (1983). An exploratory study of the relationships between reported imagery and the comprehension and recall of a story. *Reading Research Quarterly, 19,* 110-123.

Sadoski, M. (1985). The natural use of imagery in story comprehension and recall: Replication and extension. *Reading Research Quarterly, 20*, 658-667.

Sadoski, M. (1992). Imagination, cognition, and persona. *Rhetoric Review, 10,* 266-278.

Sadoski, M. (1999). Comprehending comprehension [Essay review of the book *Comprehension: A paradigm for cognition*]. *Reading Research Quarterly, 34,* 493-500.

Sadoski, M. (2002). Dual coding theory and reading poetic text. *Journal of the Imagination in Language Learning and Teaching, 7*, 78-83.

Sadoski, M., & Goetz, E. T. (1985). Relationships between affect, imagery, and importance ratings for segments of a story. In J. A. Niles & R. Lalik (Eds.), *Issues in literacy: A research perspective* (pp. 180-185). Thirty-fourth Yearbook of the National Reading Conference. Washington, DC: National Reading Conference.

Sadoski, M., Goetz, E. T., & Avila, E. (1995). Concreteness effects in text recall: Dual coding or context availability? *Reading Research Quarterly, 30*, 278-288.

Sadoski, M., Goetz, E. T., & Fritz, J. (1993). Impact of concreteness on comprehensibility, interest, and memory for text: Implications for dual coding theory and text design. *Journal of Educational Psychology, 85*, 291-304.

Sadoski, M., Goetz, E. T., & Kangiser, S. (1988). Imagination in story response: Relationships between imagery, affect, and structural importance. *Reading Research Quarterly, 23*, 320-336.

Sadoski, M., Goetz, E. T., Olivarez, A., Lee, S., & Roberts, N. M. (1990). Imagination in story reading: The role of imagery, verbal recall, story analysis, and processing levels. *Journal of Reading Behavior, 22*, 55-70.

Sadoski, M., Goetz, E. T., & Rodriguez, M. (2000). Engaging texts: Effects of concreteness on comprehensibility, interest, and recall in four text types. *Journal of Educational Psychology, 92,* 85-95.

Sadoski, M., & Paivio, A. (1994). A dual coding view of imagery and verbal In R. B. Ruddell, M. R. Ruddell, & H. Singer (Eds.), *Theoretical models and processes of reading* (4th ed.) (pp. 582-601). Newark, DE: International Reading Association.

Sadoski, M., & Paivio, A. (2001). *Imagery and text: A dual coding theory of reading and writing.* Mahwah, NJ: Lawrence Erlbaum Associates.

Sadoski, M., Paivio, A., & Goetz, E. T. (1991). A critique of schema theory in reading and a dual coding alternative. *Reading Research Quarterly, 26,* 463-484.

Sadoski, M., & Quast, Z. (1990). Reader response and long term recall for journalistic text: The roles of imagery, affect, and importance. *Reading Research Quarterly, 25,* 256-272.

Strain, E. & Herdman, C. M., (1999). Imageability effects in word naming: An individual differences analysis. *Canadian Journal of Experimental Psychology, 53*, 347-359.

Strain, E., Patterson, K., & Seidenberg, M. S. (1995). Semantic effects in single-word naming. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 21*, 1140-1154.

Strain, E., Patterson, K., & Seidenberg, M. S. (2002). Theories of word naming interact with spelling-sound consistency. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *28*, 207-214.

Terwilliger, P. N., & Kolker, B. S. (1982). The effects of learning confusable words on subsequent learning of high or low imagery words. *Reading World, 21,* 286-292.

van der Veur, B. W. (1975). Imagery rating of 1,000 frequently used words. *Journal of Educational Psychology, 67,* 44-56.

Venezky, R. L., & Massaro, D. W. (1987). Orthographic structure and spelling-sound regularity in reading English words. . In A. Allport, D. MacKay, W. Prinz, & E. Scheerer (Eds.), *Language perception and production: Relationships between listening, speaking, reading, and writing* (pp. 159-179). New York: Academic Press.

Williams, J. D. (1998). *Preparing to teach writing: Research, theory, and practice* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates.

West, W. C., O'Rourke, T. B., & Holcomb, P. J. (1998). Event-related brain potentials and language comprehension: A cognitive neuroscience approach to the study of intellectual functioning. In S. Soraci & W. J. McIlvane (Eds.), *Perspectives on fundamental processes in intellectual functioning* (pp. 131-168). Stamford, CT: Ablex.

Wolpert, E. M. (1972). Length, imagery values, and word recognition. *Reading Teacher*, *26*, 180-186.

Evolved dual coding mind and related species Dual coding theory and the brain Evolution of the dual coding mind Peak evolved mind and performance. Rubrics: Thought and thinking Cognition Mental representation Dual-coding hypothesis. Download now Mind and its evolution : a dual coding theoretical approach Allan Paivio.: Download PDF book format. Download DOC book format. 5 Special Topics 5.1 Dual Codes . . . 5.2 Group of a Code . . . 59 59 60. 2.Â The author believes that reading actively is innitely more productive than reading passively. Ac-cordingly, as you read this book, you will notice reading questions interspersed throughout the text. These questions are meant to be straight-forward checks of your reading comprehension.Â Through our study of error-control codes, we will model our data as strings of discrete symbols, often binary symbols {0, 1}. When working with binary symbols, addition is done modulo 2. For example, 1 + 1 â‰¡ 0 (mod 2). We will study channels that are aected by additive white Gaussian noise, which we can model as a string of discrete symbols that. Dual-coding theory, a theory of cognition, was hypothesized by Allan Paivio of the University of Western Ontario in 1971. In developing this theory, Paivio used the idea that the formation of mental images aids in learning (Reed, 2010). According to Paivio, there are two ways a person could expand on learned material: verbal associations and visual imagery. Dual-coding theory postulates that both visual and verbal information is used to represent information (Sternberg, 2003). Visual and verbal