CHAPTER 1

A Dual Coding Perspective on Encoding Processes

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Dual coding theory emerged several decades ago when a systematic research program was undertaken to examine the role of imagery in human cognition and, if warranted, to restore imagery to its "rightful place" alongside the language processes that then dominated the interests of cognitive psychologists. Early research efforts at the University of Western Ontario demonstrated the contribution of nonverbal processes to human cognitive behavior, even when that behavior involved language (e.g., Paivio, 1963, 1965, 1966; Paivio & Yarmey, 1965; Paivio & Yuille, 1966). We still find useful this work and that of other early investigators, summarized in Paivio (1971/1979), despite the considerable developments that have occurred in the intervening years as more and more scholars have applied their scientific skills to the study of imagery. Paivio (1986) provides a dual coding perspective on some of this recent work. These earlier sources give a more complete description of dual coding theory, which provides for us a useful organization of many cognitive phenomena.

In this chapter we first outline a few basic features of the dual coding model and then we apply those features specifically to an understanding of the diverse operations known collectively as encoding processes. We particularly try to correct the erroneous view that dual coding theory is a theory only about or even primarily about imagery, rather than about the role of both verbal and nonverbal processes in cognitive behavior. Thus, we give equal space to the several distinct processes proposed in dual coding theory, including those that concern imagery. A second objective is to demonstrate the empirical continuities that we see in the work of experimental psychologists over the last century. This goal is motivated by our conviction that progress in understanding human cognition will come only through the accumulation and systematic treatment of masses of conceptually related findings, a view of science captured in the constructive empiricism and convergent operationism on which dual coding theory is based (Paivio, 1971/1979, 1975, 1986a). Given this view, cognitive psychologists should not be too ready to ignore valuable observations from earlier generations of imaginative researchers.

Our major thesis is that dual coding theory (Paivio, 1971/1979, 1986a) provides a systematic and informative perspective on the complex encoding opera-

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tions that transform and elaborate stimuli which come in contact with the cognitive system. Encoding processes are major determinants of how well new information is learned and remembered, as shown by demonstrations that incidental and intentional learning are equivalent under effective encoding instructions, and that memory performance varies both with instructions to encode information in particular ways and with the amenability of materials to different types of encoding. Moreover, many mnemonic and imaginal strategies benefit learning primarily because they stimulate effective encoding operations.

Dual Coding Theory

A basic premise of dual coding theory is that mental representations retain some of the concrete qualities of the external experiences from which they are derived, in particular qualities associated with distinct linguistic and nonlinguistic events (Paivio, 1971/1979, 1986a). The unique features of these two domains are accommodated in dual coding theory by separate verbal and nonverbal symbolic systems that operate in fundamentally different ways (see Figure 1.1). In essence, dual coding theory postulates verbal and imaginal representations that encode word and object information, respectively, as well as connections that exist between (a) sensory events and the symbolic representations, (b) verbal and imaginal representations, and (c) representations within the two symbolic systems.

Verbal representations or *logogens* (cf. Morton, 1969, 1979) are wordlike entities comprised of visual and phonemic features, with the latter perhaps having priority in human cognition. Logogens demonstrate certain distinct properties characteristic of language. In particular, language consists of discrete, categorical, and separate units that can be isolated from one another and even combined to produce new units. Discrete letters or phonemes (e.g., n, o, s, e) are combined into discrete morphemes or words (e.g., "nose") that can be combined further into phrases (e.g., "bloody nose") and sentences. A second property of language is that it is sequentially constrained with meaning determined by the temporal and serial order of the elements. For example, "nose" is different from "eons" and "John hit" from "hit John." Sequential constraints are further demonstrated by our inability to verbalize more than one sound or word at a time. Thus, we cannot contemplate as words "bloody" and "nose" simultaneously. Finally, words such as "nose" are usually arbitrary patterns that bear little resemblance to the things for which they stand, and such inventions have little meaning except through their mental connections with other events.

Imaginal representations or *imagens* encode modality-specific information about nonverbal, perceptual, and sensory-motor experiences, conscious imagery being one way that imagens manifest themselves. According to dual coding theory, visual–spatial imagens demonstrate the distinctive properties of the nonverbal system better than motor imagens, which are organized both sequentially (as is language) and synchronously. In particular, objects are stored as integrated,

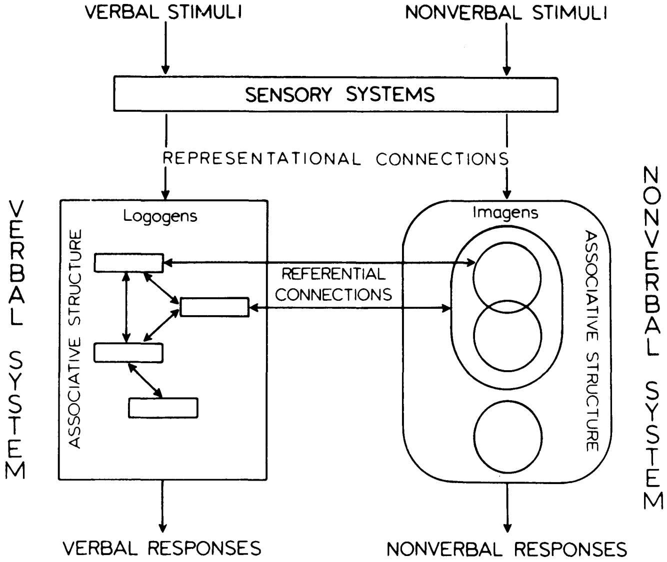

FIGURE 1.1. Schematic depiction of the structure of verbal and nonverbal symbolic systems. From *Mental representations: A dual coding approach* by A. Paivio, 1986, New York: Oxford University Press. Copyright © 1986 by Oxford University Press. Reprinted by permission.

continuous, analogue, or holistic representations that cannot easily be partitioned into discrete elements comparable to letters. Imagens may have identifiable parts (often associated with names) but these parts can be conceptualized as a hierarchical collection of imagens nested within other imagens and are only rarely isolated to be recombined as different objects. Thus, an imagen for "nose" is nested along with other parts in an imagen for "face" and parts themselves can often be broken into finer segments (e.g., "nostrils"). The continuous, analogue nature of imagens is further demonstrated by the observation that presentation of part of an image usually redintegrates the whole and by their amenability to smooth and continuous spatial transformations. For example, we recognize people from partial views (perhaps of a nose) and can imagine translations and other spatial changes of our conscious images. Imagens also demonstrate a synchronous or parallel quality that is absent in language. For this reason, a single imagen can represent simultaneously even complex thoughts that require many words or propositions to describe. A single image for the two-word phrase "bloody nose" provides a simple example of the richness of imaginal representations. Finally, imagens for such objects as "nose" are not arbitrary because they retain some of the object's perceptual properties and are therefore isomorphic with or analogous to the things for which they stand.

The dual coding description of these relatively concrete mental representations, logogens and imagens, is still incomplete, but research on the perceptual representation of words and objects is providing a more elaborate account of these codes. One fundamental question is whether word and object codes are multiple traces of highly specific, concrete, episodic events (i.e., exemplars) or more generic, abstract, prototypical codes in which single representations stand for each word and object (i.e., types). Dual coding theory does not include a level of representation that is any more abstract than logogens and imagens (e.g., a "nose" concept that accommodates both images and words, including synonyms and translations), primarily because present findings can be explained without the hypothesis of single type nodes corresponding directly to concepts or ideas. Thus, the abstract representations of common coding or propositional theories (e.g., Rosenberg & Simon, 1977; Vanderwart, 1984) are superfluous.

According to dual coding theory, logogens and imagens are implicated in three different levels or kinds of processing. *Representational processes* operate whenever logogens or imagens are activated, but they are perhaps most purely seen when mental representations are stimulated relatively directly by suitable words or objects external to the organism. Representational processes include low-level, stimulus-driven aspects of perceptual recognition or identification and are governed largely by the physical characteristics of and experience with the words or objects themselves. Thus, familiarity is the major psychological correlate of representational processes. Word and picture identification tasks are relatively pure measures of this level of processing, which generally operates quite rapidly and automatically. However, more effortful representational processes also contribute to the identification of nonsense materials, either words or objects. For example, someone for whom "nos" and " < " are meaningless patterns may encode them as the word "nose" or as an image of a nose, respectively. The basis of the encoding in both cases is the perceptual similarity of the stimulus to logogens or imagens for "nose" and the contribution of representational processes to the encoding of novel stimuli has a long history in psychology (Bartlett, 1932; Gibson, 1929; Woodworth, 1938; Wulff, 1922, cited in Gibson, 1929) that extends to the present time (Bregman, 1977).

Referential processes operate when imagens and logogens activate representations in the other symbolic system using connections that develop between verbal and imaginal representations as a consequence of increasingly complex experiences with objects and their names. The multiple connections between imagens and logogens provide only potential pathways between the symbolic systems because referential processes are probabilistic. Given appropriate circumstances, however, between-system connections allow the verbal and nonverbal systems to process information together, sometimes in a coordinated and complementary fashion. The actual operation of these referential processes is most purely reflected in such tasks as imaging to words and naming pictures. Thus, referential connections permit the word "nose" to activate various imagens and appropriately shaped objects to activate various logogens (e.g., "nose," "smell," "nez").

Associative processes operate when logogens activate other logogens and imagens activate other imagens. These processes use within-system connections among imagens in the nonverbal system and among logogens in the verbal system, including connections among verbal representations of abstract words that do not refer to concrete things. Such associative networks store knowledge about our verbal and nonverbal worlds. For example, the logogen for "nose" is associatively connected to other logogens (e.g., "smell," "part of body," "face," "red") and imagens for "nose" are associatively related to other imagens (e.g., "face," "eye," "person," "room"), including those within which it is nested. Pure measures of verbal and imaginal associative processes are rare because of between-system referential connections. Nevertheless, verbal associative networks are major determinants of performance on such tasks as word association, whereas imaginal associations are more salient in such complex imaginal tasks as cognitive mapping and (perhaps) memory for concrete schemas or scripts.

Human memory is rooted in these basic mental units and relations. In essence, our reactions to words and objects (e.g., "nose") are composite or aggregate patterns that result from the collective activation of verbal and imaginal representations through a combination of direct external stimulation and spreading activation along internal associative (e.g., "part of body") and referential (e.g., image of "boxer with bloody nose") pathways. Spreading activation occurs simultaneously along multiple paths at each of several successive stages. The sophistication and complexity of human thought arises because the networks are complex and elaborate with multiple connections both within and between the verbal and imaginal systems. Moreover, the networks are dynamic and variable rather than static, with the momentary strengths of connections being especially sensitive to the verbal and nonverbal context. For example, the context of "bloody" produces different imaginal (e.g., "boxer in ring") and verbal (e.g., "fight") reactions to "nose" than would some other context. Dual coding theory maintains that these basic associative and referential structures are sufficiently powerful to explain more complex networks, including those used in metacognitive processing. For example, instructions "to image" provide a verbal context that increases the probability of imaginal reactions relative to instructions "to associate."

In the remainder of this chapter, we describe mnemonic encoding operations that implicate representational, referential, and associative levels of processing for both verbal and nonverbal materials. Examples of the six types of encoding revealed by this dual coding analysis are presented in Table 1.1. Each type has an extensive literature and we focus on the actual encoding operations, mentioning only briefly their mnemonic consequences or other stages of memory. We specifically emphasize tasks that show the encoding operations in as pure a form as possible within the limitations imposed by interactions among the different levels of processing and the assumption that common mental representations may be involved. Such tasks permit us to observe, albeit indirectly, encoding ease as measured by latencies, ratings, self-reports, and other indicators, as well as the subject, item, and situational factors that influence encoding operations.

TABLE 1.1. Symbolic modalities, processing levels, and sample operations.

Modality	Level	Operations
Verbal	Representational	Reading
		Natural language mediation
		Mnemonic keywords
	Referential	Imaging
		Mental comparisons
	Associative	Free association
		Category production
		Free-recall clustering
		Associative priming
Nonverbal	Representational	Perceptual identification
		Assimilation to known object
	Referential	Picture naming
		Object-word comparisons
	Associative	Integration by compound imagery
		Method of loci and cognitive maps
		Concrete scripts and schemas

Encoding Processes for Verbal Stimuli

Memory traces for language result from a combination of representational, referential, and associative encoding processes. These levels of encoding depend partly on one another in that a verbal stimulus can only engage imaginal and verbal associative encoding processes after prior activation of a logogen. However, representational encoding does not guarantee referential or associative processing, which are in turn relatively independent of one another.

Representational Encoding of Unfamiliar Verbal Stimuli

According to dual coding theory, novel verbal stimuli (e.g., the Finnish word "norsu" and the nonsense syllable "cit") are made more memorable by being encoded as familiar words or phrases (e.g., as "nurse" or "city"). Much of the relevant research on representational access has used nonsense syllables, which were recognized even by Ebbinghaus as varying in both memorability and meaningfulness (Jenkins, 1985). The latency to think of a word provides one direct indicator of the ease with which nonsense syllables activate words or phrases (Schaub & Lindley, 1964). Mediators can be produced quickly, as demonstrated by Prytulak (1971) who found that mediators (mostly single words) occurred 96% of the time at a 4-sec rate of presentation. Stark and Calfee (1970) found that the time to transform nonwords (from one to five letters in length) to single words was less than the time to think of sentence mediators and the difference between the two increased as the number of letters increased.

Other indicators of encoding ease have been based on production measures or ratings, including reports of natural language mediation (Montague, Adams, &

Kiess, 1966), pronounceability ratings (Heim, 1973; Underwood & Schulz, 1960), association value (Archer, 1960; Paivio & Madigan, 1968), and meaningfulness (Krueger, 1934). These variables have been shown to correlate with one another (Prytulak, 1971) suggesting that a common mechanism contributes to them all. In particular, the latency for word associates to nonwords is correlated with other measures of ease of encoding (e.g., Johnson, 1964; Ley & Locascio, 1970). For example, Johnson (1964) obtained a correlation of −.70 between association value and the latency to say a word. Schaub and Lindley (1964) reported that the median latency was 2.22 sec for high association value syllables, but 8.22 sec for low association value syllables. The authors also found that mediators for high association value syllables were more likely to be single words, to retain the order of the letters, and to be shared with other subjects (i.e., to have higher commonality or dominance) than were mediators for low association value syllables.

The spontaneous reported use of natural language mediators during learning provides information about the stimulus, subject, and situational factors that influence the encoding of nonwords as words. Kiess (1968) observed that the percentage of subjects reporting a mediator increased from 32 to 61 to 87% for low, medium, and high association value syllables, respectively. At the same time, the mean latency of mediators decreased from 2.09 to 1.91 to 1.77 sec. Kiess and Montague (1965) found that all subjects reported mediators for some items, but that the number of mediators reported on the last trial varied widely across subjects from two to eight (out of a possible eight). Verbal reports also showed that some subjects deliberately attempted to form such mediators, indicating a possible role for strategic factors. Kiess and Montague (1965) demonstrated that the number of mediators increased across trials and Kiess (1968) that the percentage of mediators for low association value stimuli increased from 32% at a 2-sec rate of presentation to 47% at a 4-sec rate. In the latter study, the average latency of mediators also increased with presentation time, suggesting that the extra time made it possible for subjects to access more remote mediators.

Several researchers have successfully analyzed nonword encoding operations in terms of the similarity of nonsense syllables to familiar words, an approach consistent with the dual coding position that this recoding involves perceptual features at the representational level. Johnson (1962) had subjects rate whether or not consonant-vowel-consonant trigrams (CVCs) occurred as syllables in the English language and found that easy to pronounce CVCs (Underwood & Schulz, 1960) were more likely to occur as syllables than difficult to pronounce CVCs. In a second study, subjects generated English words that contained the CVCs and the number of generated words predicted ease of learning of the trigrams. More specifically, Greenberg and Jenkins (1964; Jenkins, 1966, 1985) found that the number of phonetic and orthographic substitutions necessary to create words from nonsense syllables (trigrams in one study and four-letter units in another) predicted rated association value and meaningfulness. A similar analysis by Prytulak (1971) showed that such transformations as suffixing were simple and easily decoded (e.g., "cit" transformed to "city"), whereas others, such as substitution of letters and then suffixing, were more complex and difficult to decode (e.g., "zyt" transformed to "city"). A transformational hierarchy predicted ease of learning and pronounceability of the nonsense syllables as well as the latency, probability, and uncertainty of mediator production.

These studies demonstrate that nonsense syllables are often encoded as words, that perceptual similarity is the basis for the encoding, and that memory is largely determined by the ease with which such correspondences are effected. The vocabulary-learning literature supports this characterization. Learning benefits from strategies that explicitly use familiar representations to encode the new words, for example, the systematic use of root words or morphemes (e.g., Pressley, Levin, & McDaniel, in press) and the keyword method (e.g., Atkinson & Raugh, 1975; Desrochers & Begg, Chapter 3, this volume; Pressley, Levin, & Delaney, 1982), which relates an unknown vocabulary word to a familiar concrete keyword or phrase that sounds like the new term (e.g., "couteau" encoded as "cut toe").

Even uninstructed subjects report spontaneous keyword-like mediation and these reports are correlated with learning. For example, in a recent vocabulary learning study with Alain Desrochers and Michael Pressley, we questioned 21 control subjects about the strategies that they used in earlier learning phases of the study. Subjects reported using English words that sounded like the foreign word for an average of 35% of the pairs and the reported use of this technique was very stable as shown by the correlation of .90 between reported use for practice and target lists. The mnemonic relevance of these mediators was demonstrated by correlations of .50 or so between several measures of learning and the reported use of similar sounding English mediators on the target items.

This research with nonsense syllables and foreign words has shown the importance of encoding unfamiliar verbal stimuli in terms of familiar logogens and also some idea of the mechanisms involved. One benefit of such encoding is that internal connections between logogens and other cognitive units permit additional encoding processes, such as imagery, to occur.

Imaging to Words

Dual coding theory postulates that referential connections between logogens and imagens permit indirect activation of images by words, as in imagery production tasks. Moore (1915) found an average reaction time of 1.41 sec for imaging to words versus .56 sec for getting "an auditory-kinaesthetic verbal image of the word itself" (p. 208) or, in dual coding terms, activating a logogen. The difference between these latencies provides a measure of referential processing time, somewhat less than 1 sec for the concrete items used by Moore. This estimate agrees reasonably well with the estimate of ½ to 1 sec arrived at by Paivio (1971/1979) for concrete words. Paivio (1966, 1968) found that imagery latencies were slower for abstract words than for concrete words and Paivio, Yuille, and Madigan (1968) provided extensive imagery and concreteness ratings that were shown to correlate highly with latency (Janssen, 1976; Paivio, 1975). Such ratings provide a convergent measure of the ease or availability of imagery.

Similar investigations have been made of compound imagery with two or more words, although associative processes undoubtedly contribute to this more complex operation. Yuille and Paivio (1967) and Yuille (1973) obtained imagery latencies of approximately 8 sec for concrete pairs and 12 sec for abstract pairs, but faster times have been reported by others for concrete words (Segal, 1976), even for children (Pressley & Levin, 1977), and for meaningful words or phrases (Giannandrea, 1971; Paivio & Begg, 1971). The rated ease of compound imagery correlates with imagery latency and Pressley and Levin (1977) found that faster reaction times were associated with common images about which there was normative agreement, another measure of ease of compound imagery.

Measures based on imagery production and ratings are complemented by subject reports that provide data about imagery encoding under noninstructed conditions. Bugelski (1970) found imagery to be a ubiquitous response to both concrete and abstract words. When subjects described their first thought upon hearing single common words, 85% of the descriptions included an imaginal component. Retrospective reports of naturally occurring imagery, as obtained on such measures as the Individual Differences Questionnaire (Paivio & Harshman, 1983), produce somewhat lower estimates for the probability of imagery. In particular, only 42% of subjects endorsed the item: "I can form mental pictures to almost any word," although more subjects endorsed items about the use of imagery to remember (85%), reminisce (93%), read descriptions (87%), and think (76%).

Reports of spontaneous compound imagery in memory tasks vary with rate of presentation, as one might predict given the latency data. At a 3-sec rate, Paivio and Yuille (1969) found that control subjects reported imagery for only 18% of concrete word pairs and 6% of abstract pairs after one trial. However, with a 10 second rate, Richardson (1978) obtained reports of imagery for 62% of concrete pairs and 26% of abstract pairs. Instructions to image and additional trials increased the reported imagery in the Paivio and Yuille (1969) study, but even after three trials, reports were still below the level found by Richardson.

The ease of imaginal encoding varies with subject, situational, and item factors. For example, imagery latencies correlate with individual differences in imagery ability (Ernest & Paivio, 1971) and compound imagery latencies decrease with grade (Pressley & Levin, 1977). Several potent situational variables have been mentioned already, notably rate of presentation and instructions. The rated ease of compound imagery increases not only with such item attributes as imagery value and concreteness, but also with the associative relatedness of the items (Day & Bellezza, 1983). At a more molecular level, Kosslyn and his colleagues (Farah & Kosslyn, 1981; Kosslyn, 1980) found that image latency increased with object complexity, although latency was not correlated with number of features in a study by Hoffman, Denis, and Ziessler (1983). Interpretation of these findings is further complicated by the fact that complexity has perceptual effects (Long & Wurst, 1984) and is correlated with such other variables as familiarity (e.g., Snodgrass & Vanderwart, 1980) and even imagery ratings (Yuille, 1973). In the latter study, drawing images for abstract pairs took longer and involved more objects and features per object than did drawings for concrete pairs.

Observations about imagery encoding explain a number of imagery effects in both standard memory tasks (for reviews see Paivio, 1971/1979, 1986a; Richardson, 1980) and such learning strategies as the keyword method, which uses imagery to integrate the meaning of each unknown word and its keyword. The beneficial mnemonic effects of both item concreteness (Paivio & Csapo, 1969) and imagery instructions increase with additional study time, presumably because of the time required for images to be activated. In particular, imagery instructions have optimal benefits only with slow rates of presentation (Bugelski, Kidd, & Segmen, 1968; Gruber, Kulkin, & Schwartz, 1965; Wood, 1967), a conclusion that received further support in a study by Bugelski (1968), which showed that mnemonic subjects adopted a slow rate of presentation (8 sec per item) when learning was subject paced. These studies disagree somewhat as to the rate of presentation at which imagery effects first emerge, perhaps because of such uncontrolled factors as the time required for nonreferential processing (e.g., retrieval of rhyme pegwords).

Studies of image generation and studies of memory stimulate additional questions of mutual interest. For example, Pressley and Levin (1978) found that interactive imagery instructions did not facilitate recall by grade 2 children when separate words were presented but did improve recall when separate pictures were presented. These results provide indirect evidence for separate generate and integrate stages to compound imagery, an hypothesis amenable to more direct investigation by imagery production measures. The effects of complexity on imaging may also have mnemonic implications, especially since Yuille (1973) found a substantial 5-sec difference between drawing times for concrete and abstract pairs. Other research shows that subjective imagery is not inevitably associated with good memory performance (e.g., Day & Bellezza, 1983), indicating a need for further investigation of retrieval processes (e.g., Yuille, 1973) as well as the encoding operations emphasized here.

To conclude our discussion of imagery, the findings indicate that the probability and ease of imagery encoding is related to a variety of factors that also influence memory performance in predictable ways. Imagery is only one "deeper" form of encoding for language materials and we now turn our attention to associative encoding processes for verbal stimuli.

Associative Encoding of Words

According to dual coding theory, activation spreads not only to imagens but also to other logogens, as demonstrated by free associations or such restricted associates as opposites (Hollingworth, 1915), properties (Underwood & Richardson, 1956a), instances of categories (Battig & Montague, 1969), and activities

(Bower, Black, & Turner, 1979). The latency of such associates provides one measure of their ease or strength. Cattell (1889) found that free association latencies averaged 1 or 2 sec for well-practiced faculty members. The average latencies for undergraduates were 3 sec for concrete words and 4 sec for abstract words, similar to values obtained by Paivio, (1966). By subtractive procedures, Cattell (1889) concluded that the actual association time was approximately half a second for his two practiced subjects.

Ease of association has also been measured by commonality or dominance of associates, retest stability, order and number of responses in continuous association, number of different words given for each stimulus, judgments of general associability (Kamman, 1968; Murray, 1982), and ratings of such specific relations as typicality (Katz, 1983; Uyeda & Mandler, 1980), similarity (Flavell & Johnson, 1961), and synonymity (Whitten, Suter, & Frank, 1979; Wilding & Mohindra, 1981). For a given type of relation, correlations among the various measures suggest a common underlying mechanism. In particular, associative reaction time decreases with stability (Hull & Lugoff, 1921) and with commonality as shown by Schlosberg and Heineman (1950), who found a correlation of −.80 between log association time and commonality (see Murray, 1978 for a brief history of Marbe's Law). Commonality also correlates with the order and stability of associates (Fox, 1970; Howell, 1970) which are themselves related (Szalay & Deese, 1978).

Associative processes also contribute to priming tasks in which related words facilitate identification (Rouse & Verinis, 1962), lexical decisions (Meyer & Schvaneveldt, 1971), and naming (Warren, 1977) for target items and interfere with such responses as color naming that compete with the primed response (Warren, 1972). Sentence verification (Collins & Quillian, 1969), category judgment (Schaeffer & Wallace, 1969), and other semantic decision tasks invoke similar processes. Related words have been selected for these priming tasks primarily from association norms, thus demonstrating the general equivalence of the two paradigms. Moreover, priming sometimes varies specifically as a function of associative strength (e.g., Rouse & Verinis, 1962; Warren, 1974), but not always (e.g., Warren, 1977).

Many variables influence verbal associative reactions. During childhood, age is associated with decreases in associative latencies (Anderson, 1917) as well as changes in the nature of associations (Nelson, 1977). Specific experiences have selective effects on associations. For example, Foley and MacMillan (1943) found that ambiguous words elicited more "legal" associations from law students and more "medical" associations from medical students. Hollingworth (1915) showed that practice increased the speed of opposite generation, but that association time was still longer than reading time, even after 100 repetitions. One important situational determinant of associative encoding is verbal context, including words that indirectly prime common or shared responses. Convergent association is sometimes slow and difficult, as shown by Yuille and Paivio (1967) who obtained an average latency of 8.5 sec for unrelated word pairs (see also

Colman & Paivio, 1970; Yuille & Paivio, 1968). At the other extreme, category names can be generated in only 1.6 sec with multiple instances from memorized categories (Smith & Magee, 1980, Exp. 4).

The effects of context vary with a host of factors, including the number of shared similarities and rated similarity or cooccurrence of the words (Flavell & Johnson, 1961), the strength of the common responses in the separate associative hierarchies (Coleman, 1964), the number and proximity of context words (Howes & Osgood, 1954; Judson, Cofer, & Gelfand, 1956), the strength of competing responses (Underwood, 1957), and instructions (Reed, 1946; Underwood & Richardson, 1956b). Similar processes explain how instructions to associate with particular types of responses (e.g., synonyms or properties) bias the spread of activation to relevant pathways (e.g., Cattell, 1887). Such self-instructions can also be produced indirectly, as when massing opposite-evoking words early in a free association list increases the number of opposites to later words (Wynne, Gerjuoy, & Schiffman, 1965). The early words presumably activate the logogen for "opposite."

Verbal associative mechanisms contribute to elaboration and organization effects in memory. Elaboration refers here to encoding processes that activate information stored about the word in the verbal system and is related to the idea of depth or levels of processing (Craik & Lockhart, 1972). For example, Paivio (1986b) summarized several studies of elaboration processes with semantic equivalents. One study by Paivio and Lambert demonstrated that generation of synonyms or translations produced better recall for the presented words than did copying them. A second pilot study showed that incidental memory for stimulus words increased as the normative difficulty of synonym generation increased, perhaps because more associative activation occurred when synonym generation was difficult.

Organizational processes operate when presented words are related to one another either directly or indirectly. Direct associations between presented words benefit free recall (Deese, 1959; Jenkins & Russell, 1952), interfere with recognition memory (Underwood, 1965), and either benefit (Murray, 1982) or interfere with (Underwood & Ekstrand, 1968) such associative tasks as paired-associate learning. Convergent associations in which presented words share a common associate contribute to such memory phenomena as clustering in free recall (Borges & Mandler, 1972; Bousfield, 1953; Hudson, 1968), mediational effects in paired-associate learning (Bellezza & Poplawsky, 1974; Miller, 1970), intrusion errors in recognition memory (Rubin, 1983; Underwood, 1965), instantiation effects in sentence memory (Anderson & Ortony, 1975; Gumenik, 1979; Marschark & Paivio, 1977), memory for schemas or scripts (Bower et al., 1979; Kahn, 1985), and the effects of schematic learning strategies (Buzan, 1974; Dansereau, Collins, McDonald, Holley, Garland, Diekhoff, & Evans, 1979; Holley & Dansereau, 1984; Novak & Gowin, 1984). Our approach to the more complex tasks can be illustrated for instantiation effects. In essence, close cues (e.g., "basket") are convergent associates of the words in the sentences (e.g., "The *container* held the *apple*"), whereas distant cues (e.g., "bottle") are not.

Association and memory tasks demonstrate some precise correspondences. To illustrate, Coleman (1963) found that the latency (or order) of individual word associations predicted paired-associate intrusion errors, and Miller (1970) found a correlation of .71 between the strength of primary convergent associations and paired-associate learning by a different group of subjects. We conclude from this and other research that relatively direct indicators of verbal associative processes demonstrate effects having parallels in memory and learning tasks. Verbal associative encoding is the last of the three encoding processes for words and we describe next research on encoding processes for nonverbal materials.

Encoding Processes for Nonverbal Stimuli

Dual coding theory characterizes the encoding of nonverbal stimuli in terms of representational, referential, and associative processes analogous to those that we have discussed for language. Objects are encoded representationally when they activate familiar imagens, which in turn can activate logogens and other imagens by referential and associative processes.

Representational Encoding of Novel Objects

Unfamiliar figures access familiar imaginal representations by processes based on perceptual similarity and transformation. The operation of these processes is demonstrated when subjects draw novel shapes from memory. Gibson (1929) found changes in 43% of reproductions of various nonsense figures and classified 32% of those changes as object assimilations, that is, as reproductions that resembled familiar objects more than did the original stimuli. Verbal reports confirmed that the nonsense figures aroused impressions of objects and that some subjects used assimilation as a deliberate strategy. Even instructions to remember literal impressions of the stimuli did not inhibit meaningful images based on perceptual similarities between the nonsense forms and familiar objects.

Verbal responses have also been used to indicate meaningful encoding of random shapes and nonsense forms (e.g., Danks, 1972; Vanderplas & Garvin, 1959) as well as such nonrandom figures as Blissymbols (Yovetich, 1985). In the Vanderplas and Garvin study, an average of 40% of subjects gave labels for the figures or said that they were reminded of some object. None of the figures was completely meaningless, the lowest association value being 20%. Ellis, Muller, and Tosti (1966) mentioned two other measures of encoding ease, the number of responses in a continuous production task (i.e., frequency or meaningfulness) and the proportion of subjects giving the primary response (i.e., dominance or consistency). Yovetich (1985) measured the proportion of subjects guessing the appropriate concept for Blissymbols and also had subjects rate their representativeness using pictorial appropriateness as one criterion.

No one appears to have used latencies (or stability) to measure the ease of encoding nonsense figures, although such encoding occurs quickly even with brief presentations (Smith, 1914) and appears to be a compelling form of encoding. Gibson (1929) found that it was difficult to suppress meaningful perceptual encoding and the spontaneity of visual encoding has been used to explain the greater Stroop effect observed with Chinese ideographs than with English words (Biederman & Tsao, 1979). Rivera (1959) showed that even subjects learning shared arbitrary labels for different nonsense forms still used distinct perceptual encodings of the individual stimuli to mediate learning. Thus, unique representational codes of the sort discussed here occur even when not required by the task.

Few researchers have investigated relations among the various measures to determine their convergent validity. Yovetich (1985) found a positive relationship between ratings of representativeness and a production measure of guessability. Ellis et al. (1966) varied consistency, by, frequency, and association value independently of one another. Results from paired-associate learning suggested that association value was the most potent variable of the three and that the effects of ease of encoding were stronger for complex figures than for simple ones. However, Ellis et al. (1966) did not report statistical analyses or the correlations among the various measures.

Despite the use of verbal responses in these measures, several findings indicate that the responses reflect largely the degree to which nonsense shapes resemble concrete objects (Paivio, 1971/1979, p. 191). In particular, the interpretation of nonsense figures can be controlled by manipulating visual attention to different parts of the figure (Freeman, 1929) and the representativeness and guessability of Blissymbols are related to concreteness and imagery ratings (Yovetich, 1985). The visual nature of the encoding processes is also obvious in nonsense figures that elicit consistent associations (e.g., over 80% of subjects labeled one of Danks's figures a "rabbit"). This evidence is still limited, however, and some verbal report measures (e.g., meaningfulness) are undoubtedly contaminated by referential and associative processes.

Several variables affect the likelihood of perceptual encoding. Ellis and Homan (1968) found indirect evidence from recognition memory that prior paired-associate learning of irrelevant materials increased the tendency to identify nonsense forms with familiar imagens that had names and facilitated recognition almost as much as prior learning of relevant responses. The paired-associate learning had no effect when subjects were explicitly given meaningful encodings for the figures, presumably because perceptual encoding was already maximized. Other research has shown that appropriate verbal labels can prime specific interpretations of nonsense figures (Carmichael, Hogan, & Walter, 1932; Ellis, 1968; Pfafflin, 1960) suggesting that the effect of label relevance in Ellis and Homan may have been stronger with less time between tasks or with instructions about response relevance.

A number of studies have shown the importance of representational encoding for memory. For example, the number of object assimilations in Gibson (1929) varied widely across subjects and correlated with amount recalled ($r = .71$). Ellis and Muller (1964) explicitly asked what shapes "looked like" and subsequently found that learning the modal responses facilitated subsequent learning of new responses for the stimuli and, under certain conditions, even recognition relative to similar distractors. Yovetich (1985) showed that the representatives of Blissymbols predicted performance on several memory tasks, even with concreteness and imagery value controlled.

Research on shape mnemonics (e.g., see visual alphabets in Yates, 1966) has also demonstrated the importance of representational access for memory. The letter learning component of the Laubach method involves images that look like the corresponding letters and begin with the same sound (Laubach, Kirk, & Laubach, 1971). To illustrate, image an "f" as a flower with leaves at the crossbar and a blossom at the top. Laubach et al. (1971) described the ease with which nonreading adults acquire the system and apply it to reading text. Using a similar technique, Isgur (1975) obtained 100% success at letter identification with reading-disabled children after only 5 to 10 min of practice per letter. Isgur also found that even commonly reversed letters were easily learned (e.g., "b" and "d"). Similar strategies or instructions to think of objects that "look like" the patterns to be learned ought to facilitate the many learning tasks that involve novel shapes (e.g., sign language, pictographic languages, foreign scripts such as the Greek letters used in statistics, identification of countries in geography or microscopic organisms in biology, fingerprints).

Activation of familiar imagens by unfamiliar patterns can be studied relatively directly and contributes to our understanding of the processes by which such patterns are learned and remembered. One of the ways that representational encoding facilitates memory is by enabling the learner to invoke higher level processes, including referential encoding (i.e., naming), to which we now turn.

Naming Objects

Mental connections between imagens and logogens permit referential encoding of nonverbal stimuli, an operation that is invoked whenever we name pictures or objects. Although rapid, naming colors and pictures takes longer than reading words (Cattell, 1886a,b). Moore (1915) found that the average time to think of names was 821 msec for pictures versus 562 msec for words. The difference (259 msec) provides one estimate of referential processing time and agrees well with the 260-msec estimate that Potter and Faulconer (1975) obtained by subtracting word-naming latencies from picture-naming latencies. The relative slowness of naming is probably not a result of differential ease of identification, because pictures and words have similar perceptual or identification thresholds (Cattell, 1886a, b; Fraisse, 1968; Moore, 1915), and pictures are categorized even faster than words (Potter & Faulconer, 1975). The difference between identification and naming times for pictures, 227 msec in Moore and 314 msec in Fraisse, provides another estimate of referential processing time.

With respect to other indicators of naming ease, Lachman (1973) reported a positive relation between naming latency and uncertainty or codability as measured by the number and proportion of different labels given for each picture (i.e., commonality). Uncertainty decreases with the number of subjects giving the dominant response (Snodgrass & Vanderwart, 1980) and with the percentage of repetitions (i.e., stability) when pictures are named on two occasions (Butterfield & Butterfield, 1977). Butterfield and Butterfield (1977) also showed that agreement with adult names decreased with uncertainty, especially for young children (4 year olds).

A variety of variables influence the ease of naming. Naming latency decreases with word frequency (Oldfield & Wingfield, 1964, 1965) and increases with age of acquisition (Carroll & White, 1973), although Lachman (1973) reported individual variation in which of these was the better predictor. Frequency has only modest effects on picture identification (Wingfield, 1968), making early perceptual processes an unlikely locus for the effect. However, some of the familiarity effect may result from response production factors (e.g., number of syllables and pronounceability) rather than referential processes. Frequency or practice has also been studied experimentally. Practice benefits picture naming more than reading but never erases the reading superiority (Fraisse, 1960, 1968). For example, color naming still requires an extra 121 msec even after 12 days of practice (Brown, 1915). Oldfield and Wingfield (1964, 1965) reported that unfamiliar pictures benefitted more from practice than familiar objects, but Bartram (1974) concluded that the differential practice effect for familiar and unfamiliar materials was less for photographs than for line drawings.

Familiarity and practice effects implicate age as a central factor in naming. Picture naming develops early, perhaps without specific training (Hochberg & Brooks, 1962), and is as fast as object naming for even 2-year-old children (Zaft & Daehler, 1979), although Nelson (1972) showed that the ability of very young children to name pictures depends on familiarity, visual ambiguity, and amount of detail in the depiction. Despite developmental advantages, Ligon (1932) reported that color naming was slower than reading by a relatively constant amount from grade 1 to adulthood, but when Stroop (1935) transformed the latencies to speeds, the difference between reading and naming increased substantially from grade 1 to grade 9. Lund (1927) even reported faster color naming than reading for young children as did Stanovich (1981), who also found picture naming to be faster than reading. Such global effects ignore the individual differences that characterize the difference between color naming and reading even among adults (Broverman, 1960; Bucci, 1984).

These relatively direct observations about referential processes contribute to our understanding of memory because naming has a positive effect on memory for pictures (Kurtz & Hovland, 1953; Paivio & Csapo, 1973; Robinson, 1970), including the ability to discriminate target pictures from same-name alternatives (Warren & Horn, 1982). Picture naming occurs more readily than imaging to words, which might help to explain why pictures are remembered better than words. That is, pictures will be more likely than words to activate both verbal and imaginal codes, and the two codes have additive effects on recall (Paivio, 1971/1979; Snodgrass & McClure, 1975). In addition, the picture superiority effect disappears when pictures and words are presented at a rate that precludes naming (Paivio & Csapo, 1969). Subjects confuse studied pictures with their names on a recognition test also indicating that names are generated spontaneously during study of pictures (Snodgrass, Wasser, Finkelstein, & Goldberg, 1974).

Picture labeling research has shown that naming develops early, but memory studies suggest that naming is an optional encoding behavior that becomes relatively automatic only later in development. For example, Conrad (1971) found that confusible names had no effect on picture memory in young children (3 to 5 years) but an increasingly disruptive effect beyond 5 years. Yarmey (1974) specifically studied the effects on learning of the normative latency of picture names. Pictures were superior to words as stimuli in paired-associate learning except when both the stimulus and response items involved long naming latencies. Presumably, the study time was insufficient to permit naming of two long latency items.

Several direct measures of naming, especially latency, have been shown to elucidate basic referential mechanisms that may help us to understand parallel effects in memory tasks involving pictures or objects. Naming is only one of two "deeper" levels of processing available for nonverbal materials and we examine next tasks and operations that reflect associative connections among imaginal mental representations.

Imaginal Associative Processing

Dual coding theory describes complex imagens as nested sets of more elementary units spatially organized into continuous, perceptual hierarchies that lack sequential constraints (Paivio, 1971/1979). Imaginal associations have been studied with such tasks as the scanning paradigm, which is analogous to verbal associative tasks and provides a latency measure of imaginal associative processes. Kosslyn (1973) had subjects focus on an imaged or described (i.e., verbal) locus of objects and measured reaction time to verify that the object contained a subsequently named part. Latencies under imagery conditions were faster and less affected by proximity to the focal point than under verbal conditions, and also varied with physical distance rather than sequential order as was the case for descriptions. Studies of cognitive maps have confirmed the effects of distance on scanning time (Kosslyn, Ball, & Reiser, 1978), although instructions influence the strength of such effects (e.g., Goldston, Hinrichs, & Richman, 1985).

The role of imagery in script production has not yet been determined directly (Rabinowitz & Mandler, 1983), but our own phenomenal imagery is strong when we think of such scripts as grocery shopping. Imaginal associations are also implicated by latency data from Barsalou and Sewell (1985), who found that scripts were produced at a constant rate, as though subjects were describing a continuous stream of perceptual events. This pattern contrasts with the bursts and pauses characteristic of production from taxonomic (i.e., verbal associative) categories. In addition, production was slower in the reverse order than in the forward order, consistent with our own script imagery and with other evidence that scenes can be (but need not be) ordered (e.g., relations among the loci in the method of loci).

The potential freedom of imaginal associations from sequential constraints has been demonstrated with a memory probe task in which subjects judge whether items belong to a previously memorized set. Reaction times to judge items as old or new (i.e., scanning times) generally increase with set size, but not if the set has been memorized as an interactive image (Bersted, 1983; Seamon, 1972). This effect occurs unless subjects have described their images verbally (Bersted, 1983; Rothstein & Atkinson, 1975) and is consistent with the hypothesis that associations between images provide access to members in a parallel or a nonordered fashion, a capacity that verbal associative structures do not provide.

Other indicators of imaginal associations have been exploited less fully but are analogous to meaningfulness and related measures. For example, Milgram and Jodelet (1976) gave Parisians place names in Paris with instructions to think of that place and then "wander with the mind's eye to the next specific element" in their mental images. The percentage of association failures for each place (a variable that correlates negatively with dominance and positively with uncertainty) predicted the probability that the place appeared on cognitive maps drawn by the subjects, suggesting that imaginal associative processes mediate map production. That cognitive maps are imaginal is also supported by the ability of people to make precise judgments of distance, orientation, proximity, and other spatial relations (Allen & Kirasic, 1985; Curtis, Siegel, & Furlong, 1981; Hirtle & Jonides, 1985), although Cattell (1895) found considerable variability among subjects in their estimates of distance and walking times as well as in their drawings of cognitive maps.

Several observations directly support our suggestion that these and related effects should be attributed to imaginal processes. With respect to cognitive maps, Moar and Bower (1983) found that all of their subjects reported images of either scenes (in a task that involved relations among locations in a city) or maps (in a task that involved relations among cities). Thorndyke and Stasz (1980) observed that visualization ability was correlated with map learning and interacted with instructions to use effective imagery strategies. A final argument for an imagery explanation (or at least against verbal processes) is the fact that nonhuman species (e.g., Olton, 1979) and young children have accurate mental maps. For example, Ratner and Myers (1981) found that children as young as 2 years of age accurately verified the contents of different rooms of a house.

Imaginal explanations appear to be challenged by research showing that knowledge about cognitive maps, objects, and scripts is at least sometimes discrete and nonveridical (Allen & Kirasic, 1985; Bower et al., 1979; Kahl, Herman, & Klein, 1984; McNamara, Ratcliff, & McKoon, 1984; Tversky & Hemenway, 1983, 1984). However, these findings are not problematic from the dual coding perspective (see Paivio, 1986a, Chapter 9). Segmentation (i.e., the tendency to divide complex spatial units into parts) and related effects may result from imaginal processes associated with nested imagens (Paivio, 1971/

1979; Palmer, 1977) or from verbal processes. Mandler and Murphy (1983) demonstrated directly that the consistency with which scripts were segmented decreased when verbal cues to segments were removed. Verbal cues (in particular, discrete names for places) may contribute to similar findings with cognitive maps.

Imaginal associative structures, as revealed in these various paradigms, have important implications for understanding memory. The enhancement of cued recall by compound imagery shows that complex images are easily redintegrated from partial cues, perhaps because images are by nature integrated and holistic (e.g., Begg, 1973). Some of the memory benefits of scripts and schemas may occur because words that are related to some episode (e.g., grocery shopping) activate complex mental scenes derived from past experiences. With respect to mnemonic and learning strategies, the method of loci uses an imaginal associative network of familiar locations and spatial learning strategies (e.g., Holley & Dansereau, 1984) represent verbal knowledge as visual networks, much as cognitive maps represent relations among discrete places.

Spatial relations appear to play an important role in both imaginal associative and memory tasks. For example, Snodgrass, Burns, and Pirone (1978) confirmed the dual coding prediction that, relative to verbal processing, imagery would enhance memory for spatial order but not memory for temporal order. Thorndyke and Stasz (1980) showed that good map learners were more likely than poor learners to encode spatial relations among places and that instructions to use such imagery strategies improved map learning, especially for high visualization ability subjects. Mandler and Parker (1976) observed that scene organization had little effect on memory for descriptive information about objects but did influence spatial information.

This concludes our examination of imaginal associative processes and of encoding operations for nonverbal materials. Pictures and objects have been shown to involve representational, referential, and associative encoding processes analogous to those used in encoding verbal stimuli and the results from direct investigations of these processes shed some light on their contribution to memory for nonverbal materials.

Conclusions

We have shown how the encoding of both verbal and nonverbal materials can be conceptualized in terms of the representational, referential, and associative processes proposed by dual coding theory. These encoding processes are amenable to direct investigation by methods that have produced findings relevant to the understanding of memory phenomena, including the effectiveness of different learning strategies. The evidence comes from studies using latency and other convergent indicators of the ease of different encoding operations to investigate how these measures are related to one another and to subject, item, and situational variables under both instructed and spontaneous encoding conditions.

A complete dual coding explanation of memory encoding would describe how metamemory knowledge controls and influences such basic encoding operations as imaging (Flavell & Wellman, 1977; Pressley, Borkowski, & O'Sullivan, 1985). The representational and processing assumptions that we have already described are in fact adequate to explain metacognitive knowledge. In essence, dual coding theory proposes that (a) reflexive knowledge of memory is represented in the same verbal and nonverbal symbolic systems as other knowledge; (b) its acquisition depends upon relevant experiences, including the reflexive application of the learning strategies themselves to strategy acquisition; (c) environmental stimuli activate relevant metacognitive knowledge, either directly (e.g., instructions to "image") or through associative and referential connections (e.g., such learning-related words and events as "remember" and classroom settings); and (d) metacognitive logogens and imagens exert control over the encoding of stimuli by priming general classes of associative or referential reactions (e.g., "image car" versus "synonym car"). Each of these aspects of metacognitive knowledge can be investigated directly. For example, Katz (Chapter 8, this volume) found reliable differences in the tendencies of instructions from various cognitive tasks to elicit verbal and imaginal modes of processing.

Many questions about cognition remain unanswered and new questions emerge every day, but experimental psychologists have learned much since Cattell's pioneering work over 100 years ago. Our fundamental knowledge about cognition is primarily empirical in nature and dual coding theory, conceived several decades ago as a general model of cognition, is a useful framework within which to conceptualize the accumulated research findings that provide an increasingly precise understanding of the memory encoding processes available in the verbal and imaginal symbolic systems.

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