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Cognitive Components of Picture Naming

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A substantial research literature documents the effects of diverse item attributes, task conditions, and participant characteristics on the ease of picture naming. The authors review what the research has revealed about 3 generally accepted stages of naming a pictured object: object identification, name activation, and response generation. They also show that dual coding theory gives a coherent and plausible account of these findings without positing amodal conceptual representations, and they identify issues and methods that may further advance the understanding of picture naming and related cognitive tasks.

Naming of objects is the fundamental ability that humans use to communicate through language (Terrace, 1985). The act of referring with names is so commonplace that people often fail to appreciate its importance. Nonetheless, the study of naming raises issues central to philosophy, linguistics, and psychology (R. Brown, 1976; Macnamara, 1982), including questions about the nature of meaning (Putnam, 1975; Quine, 1960), the relation between thought and language (Olson, 1970; Whorf, 1956), and the organization and development of semantic memory (Anglin, 1977; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976).

The apparent simplicity of naming belies the complexity of its underlying cognitive processes, which occur in three broad stages. First, an object must be identified as a member of a particular class of objects, despite variation in appearance, orientation, and settings. Then, appropriate names must be activated from among the thousands of words known to language users. Finally, articulatory commands for a specific response must be prepared and executed. Moreover, these sophisticated operations must occur rapidly and efficiently in fluent speech.

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The importance and complexity of naming necessitate its study under carefully controlled experimental conditions. The naming of pictured objects is, consequently, often used as a laboratory analogue of object naming (Lachman & Lachman, 1980). Picture naming is also of practical importance because pictures convey important information, either alone or in conjunction with written text. Overt or covert naming, therefore, occurs in many educational, occupational, and recreational activities. Picture-naming tasks are also sensitive indicators of various neurological and developmental disabilities.

Although improved understanding of the cognitive processes involved in picture naming is an important theoretical and practical goal, progress is hindered by the sheer size and breadth of the relevant literature. Available experiments reflect numerous perspectives (e.g., cognitive, developmental, educational, and neuropsychological) and appear in diverse sources. Faced with this complexity, researchers, theorists, and reviewers (e.g., Glaser, 1992; Wolf, 1991) have adopted the reasonable strategy of focusing on a limited range of specific issues relevant to naming. Reliance on this selective strategy, however, may impede the integration of diverse results into a cohesive theoretical account of naming and draw attention away from issues that transcend individual areas. Specialists may have little knowledge or appreciation of relevant issues and findings in research traditions other than their own. Established issues and techniques may be examined to the exclusion of other potentially informative questions and methods. Fundamental assumptions underlying available cognitive models may go unquestioned because it is mistakenly believed that appropriate tests are available elsewhere.

In this article, we try to redress some of these problems by examining the theoretical and empirical literature on picture naming from a wider perspective than is normally adopted. Specifically, the vast literature on item attributes, task conditions, and participant characteristics that influence naming is organized and interpreted around the cognitive representations, stages, and processes posited by dual coding theory (Paivio, 1971, 1986, 1991). The joint aims are to summarize what is

known (through 1994) about various naming stages, to show that dual coding theory provides a coherent account of existing findings, and to highlight theoretical issues and experimental methods that may advance understanding of naming.

Experimental Methods

Several methods have been used to infer which stage(s) of naming are affected by item, task, or participant variables: (a) additive factors, (b) task comparisons, (c) time course evaluations, (d) multivariate techniques, and (e) experimental object–name pairings. Each approach has inherent limitations so that converging evidence across methods is desirable.

One method used in naming experiments (e.g., Henderson, Pollatsek, & Rayner, 1987; Huttenlocher & Kubicek, 1983) is additive factors logic (Sternberg, 1969), which relies on the assumption that the processing stages of a particular task are serial and discrete. Under a strong version of this assumption, two variables that affect different stages of processing should show statistically additive effects, whereas two variables that influence the same stage should show interactive effects. However, because the assumption of discrete, serial stages may not be tenable for naming (Humphreys, Riddoch, & Quinlan, 1988; Riddoch & Humphreys, 1987), patterns of additivity or interaction between two variables cannot provide clear evidence on whether they affect separate or common stages of processing (McClelland, 1979). Empirical demonstrations of additivity or interaction between variables, nonetheless, can contribute to theory development. Interactions, in particular, permit fewer alternative explanations than additive effects, thereby constraining plausible models (Shoben, 1982).

A second method involves comparison of the effects of a specific variable on naming and on a second theoretically related task. Naming has been compared in this way with various tasks including word imaging or drawing a picture to a word (e.g., Amrhein, 1994; Paivio, Clark, Digdon, & Bons, 1989), name–picture or picture–picture matching (e.g., Wingfield, 1968), object decision (e.g., Johnson, 1992; Lupker, 1988), picture categorization (e.g., Lupker & Williams, 1989), reading (e.g., Stanovich, 1981; Wolf, 1982), word translation (e.g., Snodgrass, 1993), and recognition memory (e.g., M. Carroll, Byrne, & Kirsner, 1985; Lachman & Lachman, 1980). The value of these comparisons depends on critical and careful analysis of the common and separate processing stages required by the tasks compared in each study.

A third promising way to isolate processing stages is to evaluate behavioral data, brain activity data, or both, obtained throughout the time course of a naming task. Behavioral data have been obtained by varying the time interval between presentation of a pictured naming target and another stimulus that the participant must either ignore or respond to in a particular fashion (Glaser & Glaser, 1989; La Heij, Dirkx, & Kramer, 1990; Levelt et al., 1991b; Schriefers, Meyer, & Levelt, 1990). Brain activity during naming has been measured using event-related potentials (Stuss, Picton, & Cerri, 1986) and various brain-imaging techniques (Salmelin, Hari, Lounasmaa, & Sams, 1994). Although not yet extensively applied to picture naming, these techniques could provide valuable converging evidence concerning its stages.

A fourth approach uses multivariate techniques, such as factor analysis (Paivio et al., 1989) or multiple regression (Lachman, Shaffer, & Hennrikus, 1974), to analyze independent variables that are confounded with other variables and that are not (or cannot be) manipulated experimentally. Multivariate approaches may not permit clear interpretive links between a cluster of variables and a specific naming stage, or even attribution of gross effects on naming to specified variables. Nonetheless, these approaches are often essential for identifying factors that underlie complex intercorrelations among relevant variables.

A fifth powerful but underused strategy involves the experimental manipulation of item attributes (e.g., word frequency and object familiarity) in the learning of novel object–name pairings, followed by observation of the resulting effects on naming (Bartram, 1973; Johnson, 1992; Spenney & Haynes, 1989). Such procedures allow experimental control of confounding factors, thereby permitting causal inferences concerning relations between item attributes and various naming effects and, sometimes, the loci of such effects.

Cognitive Models of Naming

Cognitive models of object naming (Amrhein, 1994; Biggs & Marmurek, 1990; Davidoff, 1991; A. W. Ellis & Young, 1988; Glaser, 1992; Goodglass, 1993; Humphreys et al., 1988; Huttenlocher & Kubicek, 1983; Kempen & Huijbers, 1983; Lachman, 1973b; Lachman & Lachman, 1980; Levelt, 1989; Morton, 1985; Paivio, 1971, 1986; Potter, 1979; Potter & Faulconer, 1975; Ratcliff & Newcombe, 1982; Roelofs, 1992; Seymour, 1973, 1976; Snodgrass, 1984; Theios & Amrhein, 1989; Wolf, 1982) are often embedded within general frameworks intended to encompass naming and related cognitive tasks (e.g., reading and semantic comparisons). Naming is thought to include at least three broad stages: object identification, name activation, and response generation (Paivio et al., 1989). Identification of the stimulus object or picture is followed by activation of one or more candidate name representations in memory and eventuates in production of one name as an overt response.

The three naming stages usually are assumed to occur, more or less, sequentially. This assumption accords with subjective experience and with empirical evidence of voluntary control at the transitions between these hypothesized stages. That is, an object can be recognized without mental activation of a corresponding name (Lupker, 1985; McCauley, Parmalee, Sperber, & Carr, 1980), and a name can be mentally activated without overt responding (A. S. Brown, Neblett, Jones, & Mitchell, 1991; Levelt, 1989). In contrast, object identification seems to be obligatory; that is, recognition of a familiar object cannot be prevented (Boucart & Humphreys, 1992; McCauley et al., 1980). Evidence also supports the assumption that object identification occurs or begins before name activation. For example, physical identity judgments are reliably faster than name identity judgments for the same pictures (Bisanz, Danner, & Resnick, 1979; Hoving, Morin, & Konick, 1974; Kail, 1986; B. Tversky, 1979). Similarly, name activation finishes earlier than response generation because covert naming occurs more quickly than overt naming (A. S. Brown et al., 1991).

Despite their overall commonalities, cognitive models of

naming differ in certain particulars. The dual coding model (Paivio, 1971, 1986), which is our reference point in this review, incorporates the following structural and functional assumptions about the mental representations and processes involved in naming. Cognition is assumed to be based on two independent, but interconnected, nonverbal and verbal representational subsystems. The nonverbal subsystem consists of nonlinguistic object representations or *imagens* (Paivio, 1986) and the verbal subsystem of linguistic word representations or *logogens* (cf. Morton, 1969, 1979). Internal representations in both subsystems are assumed to be modality specific, retaining characteristics associated with direct perceptual experience. Most relevant to picture naming are visual characteristics of imagens and auditory–motor characteristics of logogens.

Associative connections, derived from prior experience, link representations within each subsystem. Verbal associations, for example, connect representations for names that regularly cooccur, such as an object name and its superordinate category name. Referential connections also exist between subsystems. Imagens corresponding to concrete objects are connected in a one-to-many fashion to logogens for their names; logogens are similarly connected in a one-to-many fashion to various imagens. Referential connections vary in strength and number according to prior experience with particular objects and their names and permit bidirectional mental translation between the nonverbal and verbal subsystems. Picture naming entails such referential translation in the nonverbal to verbal direction.

During naming, the stimulus picture directly initiates representational activity within the nonverbal subsystem. Activation accumulates until the recognition threshold for a particular imagen is exceeded (i.e., the pictured object is identified). Activation then spreads by way of referential connections from the imagen to associated logogens (names) in the verbal representational system. One logogen may eventually receive sufficient activation to exceed its threshold, thereby initiating production of that name as a response.

Dual coding theory also assumes that a stimulus activates multiple representations in proportion to their structural similarity to the target representation. The assumption is necessary to account for facilitative and interfering effects of similarity in a variety of semantic and episodic memory tasks (Paivio, 1986, ch. 7 & 8). We see that it also helps to explain similarity-based effects on naming.

Other models of naming parallel the dual coding model in the assumption that separate subsystems represent modality-specific information about the visual appearances of objects and the auditory–motor characteristics of words. In addition, however, many models include an abstract, amodal form of representation for the meanings of pictures and their names (e.g., Potter & Faulconer, 1975; Snodgrass, 1984; Theios & Amrhein, 1989), such that pictures activate their names primarily by way of an indirect route through the amodal semantic system. Thus, in the case of picture naming, these models assume four, rather than three, processing stages. Early visual processing generates an initial imagelike representation, which retains surface features of the stimulus object. This initial representation activates a conceptual node in the amodal semantic system that corresponds to the meaning of the object (i.e., the *concept* is identified). Meaning access then permits activation of a name representation, which in the fourth stage leads to subsequent production of that name.

Other recent models also incorporate abstract conceptual representations but differ from four-stage amodal models in the organization of naming stages. Glaser (1992) distinguished between two cognitive subsystems: the semantic system and the lexicon. During naming, the semantic system subsumes the functions attributed to the first two stages of amodal models: initial processing of objects or pictures and conceptual access. The semantic system includes abstract conceptual nodes representing the meanings of both objects and words. The lexical subsystem contains word (morpheme) representations with corresponding graphemic and phonemic features but no meaning information. Thus, Glaser assumed three naming stages: concept identification, name activation, and response generation.

Four-stage amodal models have also been elaborated to include two lexical representations, lemmas and lexemes, that are retrieved sequentially (Kempen & Huijbers, 1983; Levelt, 1989; Roelofs, 1992). *Lemmas* are assumed to be abstract lexical representations that specify the semantic and syntactic properties (e.g., grammatical class, arguments, and gender) of a word, whereas *lexemes* specify the sound form features. Accordingly, these models suggest that picture naming involves five stages: visual analysis, amodal concept identification, lemma retrieval, lexeme retrieval, and response generation.

We argue that the three-stage dual coding model is sufficient to account for current evidence concerning picture naming. In particular, we show that existing data do not compel the assumption that an amodal conceptual representation is contacted during picture naming, a conclusion also reached by others (Davidoff, 1991; Lupker, 1985; Morton, 1985) but not widely accepted by naming researchers. We suggest that amodal representations add nothing to an account of naming performance that cannot be accommodated by modality-specific representations and processes such as those posited by dual coding. Elsewhere, we have raised similar empirical and philosophical questions about the necessity of positing abstract, amodal conceptual and lexical representations to account for cognition in general (Campbell & Clark, 1988; Clark, 1987, 1994; Paivio, 1971, 1983, 1986, 1991).

A fundamental issue is how the various models account for meaning or semantics. In the dual coding view, the meaning of a stimulus comprises the entire set of nonverbal and verbal reactions typically evoked by it. A picture may arouse associated images in multiple modalities (e.g., related objects, sounds, and motor and visceral reactions), referential activation of corresponding names (e.g., object and category names), and subsequent word associations (e.g., names of related objects and properties). A stimulus word may also evoke such word associations, as well as referential images, and subsequent nonverbal associations. These various meaning relations are not ad hoc or arbitrary, as has sometimes been suggested (e.g., Potter & Kroll, 1987). They can be specified through careful task analysis and converging empirical operations applied systematically across stimulus attributes, task conditions, and participant characteristics (Paivio, 1971, 1986, 1991), as demonstrated throughout this article.

It is more difficult to give a single characterization of an amodal view of semantics or meaning. In part, this is because vari-

ous models share the assumption of amodal conceptual representations but do not necessarily share related assumptions about naming. For example, some models apparently assume that object identification occurs on access to an amodal representation (e.g., Theios & Amrhein, 1989), whereas others assume that identification occurs before amodal access (e.g., Morrison, Ellis, & Quinlan, 1992). Moreover, descriptions of the semantic or meaning information available from amodal representations are often quite brief and relatively general in nature. Among the aspects of meaning often ascribed to conceptual representations are category membership, associations, properties, attributes, and functions (Glaser, 1992; Humphreys et al., 1988; Levelt, 1989; Snodgrass, 1984; Theios & Amrhein, 1989). Dual coding theory accommodates these diverse aspects of meaning by interconnections among its modality-specific, nonverbal and verbal representations.

The assumption of abstract, amodal representations originally gained popularity because of logical and philosophical claims that modality-specific, associative theories such as dual coding could not, in principle, account for complex cognitive phenomena (e.g., Pylyshyn, 1973). Such arguments, although still occasionally presented (e.g., Glaser, 1992), appear to have little remaining force in view of the now widespread recognition that complex cognitive behaviors can emerge from associative networks.

Other factors also fostered a relatively uncritical acceptance of the need for amodal representations. Amodal views were sometimes contrasted with impoverished or incorrect interpretations of the dual coding model (Paivio, 1991), which ignored the multimodal nature of nonverbal representations and the full range of possible verbal and nonverbal meaning reactions. It was also claimed that amodal and modality specific views could not be differentiated empirically (Anderson, 1978), although the claim was weakened by the concession that the number of different codes required to account for cognitive data could perhaps be specified. The two types of theories have, in fact, been distinguished empirically in episodic memory and other cognitive tasks (Paivio, 1986). In this review, we suggest ways in which the two views could be more fully elaborated to permit meaningful tests of the alternatives in the domain of naming. Our plan is to review the effects on picture naming of three classes of variables: item attributes, task conditions, and participant characteristics. For each class of variable, we examine how the various attributes relate to the three naming stages, in turn, and consider whether the findings require the assumption of amodal codes.

Effects of Item Attributes on Naming Stages

Three classes of item attributes could be expected to influence the naming process (Paivio et al., 1989): (a) characteristics of the stimulus picture or object, such as its visual features, familiarity, or complexity; (b) characteristics of the relations between stimuli and responses, such as the nature, strength, or multiplicity of referential connections; and (c) attributes of the response word (name), such as its frequency of occurrence, familiarity, or phonological composition. Some stimulus attributes (e.g., visual quality, size, canonical perspective, and stimulus realism) can be studied using experimental manipulations, which support strong inferences about causal influences on naming. Many attributes, however, are intrinsic properties of objects or names, which are typically studied in correlational designs.

A major interpretative difficulty is that these intrinsic attributes naturally covary. A language community tends to use short, readily pronounceable names to label objects that they encounter frequently (R. Brown, 1958, 1976; J. M. Carroll, 1985), and the names for these common objects tend to be used with a high degree of consensus across speakers. Less familiar objects tend to have longer, more variable, and less consensual names. Thus, the influences of these inherent item attributes need to be teased apart from the effects of other correlated attributes using multivariate or other appropriate methods.

Object Identification

Object identification occurs rapidly (Potter & Faulconer, 1975). Participants recognize pictures presented sequentially at a rate of 16 items per second (62.5 ms per item; Paivio & Csapo, 1969) or individually under masked exposures as short as 100 ms (Biederman, 1987). Successful identification usually takes place even when objects are shown in atypical orientations, are partially occluded, or are represented by novel exemplars.

Object identification presumably occurs when a representation derived from a stimulus picture activates or matches a corresponding object representation in long-term memory (cf. the so-called Höffding step [1891] in perceptual recognition). Ease of identification, therefore, depends on (a) the efficiency of visual processes in extracting stimulus information, (b) the characteristics of long-term memory representations for objects, (c) the nature of the activation and matching processes, and (d) the degree of similarity between the stimulus and memory representations. Although these various influences on object identification can be distinguished conceptually, they are difficult to disentangle empirically.

Dual coding differs from other models of naming primarily with respect to its assumptions about the characteristics of long-term object representations and the nature of the matching process. Long-term representations (imagens) are assumed to be modality specific, not amodal. The perceptual matching process is assumed to be holistic in nature, not based on abstract features or components. The matching process underlying object identification is an important and complex problem that has received limited attention in research (Biederman, 1987; A. Tversky, 1977), despite its venerable history in discussions of perceptual recognition (see Neisser, 1967). The literature on picture naming provides some relevant data.

Initial visual analysis of a picture should be affected by various attributes that index stimulus discriminability, such as quality, size, realism, complexity, and familiarity. Some of these and other stimulus attributes (canonical perspective and modality) also may be represented as intrinsic qualities of long-term object representations. An important caution, however, is that most available work rests on the largely unproven assumption that cognitive processing is similar for objects and for the line drawings used as stimuli in most picture-naming studies.

Stimulus quality. Naming speed, accuracy, or both are ad-

versely affected if the quality of the stimulus picture is degraded by adding extraneous lines (Bisiach, 1966), blurring its focus (Sperber, McCauley, Ragain, & Weil, 1979), removing portions of line segments (Tweedy & Schulman, 1982; Wolf, 1982), or superimposing letter strings (Lupker & Sanders, 1982). Consistent with localization at an identification stage, increasing levels of stimulus degradation generally result in decreasing object recognition accuracy (Snodgrass & Corwin, 1988). Removal of information about key object parts is particularly disruptive to identification (Biederman, 1987; Biederman & Cooper, 1991b). Indirect effects of visual quality may also carry over to later naming stages (Seymour, 1976).

Stimulus size. Stimulus size also influences naming reaction times (RTs; Biederman & Cooper, 1992; McCauley et al., 1980; Theios & Amrhein, 1989). Comprehensive data are lacking, but adults apparently show optimal naming RTs for foveally presented pictures that range in size from 4° to 6° of the visual angle (Biederman & Cooper, 1992, Appendix). Pictures smaller than this size range may be difficult to discriminate; pictures larger than this range may require eye movements to permit foveal analysis. Additional empirical work is needed to map out the influence of size variations on naming, particularly in conjunction with changes in the complexity and detail of object depiction (see *Stimulus realism* and *Stimulus complexity* below).

Consistent with the argument that stimulus size influences initial visual processing, Theios and Amrhein (1989) showed that size exerted comparable effects on RTs in both naming and visual-matching tasks involving the same pictures. The size effect may arise early in analysis, perhaps before a picture is fully identified. R. Ellis, Allport, Humphreys, and Collis (1989) found that name identity matches for pictures of the same object were fastest for pairs identical in viewing angle and size, somewhat slower for those identical in viewing angle but different in size (see also Theios & Amrhein, 1989), and still slower for those differing in viewing angle. The last matches were not influenced by size, suggesting that they were based on an object-specific, size-invariant representation that develops relatively late in object processing. This object-specific representation includes visual features and becomes available before name activation, as shown by the fact that matches for different views of the same object were fast relative to matches for different objects with the same name.

Biederman and Cooper (1992) confirmed that a shape-based, object-specific, size-invariant representation mediates name activation in picture naming. They showed that the degree of facilitation in renaming a previously named picture is insensitive to changes in picture size from the first to the second naming (see *Practice* below). Size changes were encoded, however, because they had detrimental effects on recognition memory for the same pictures. These and other results (e.g., J. Miller & Hackley, 1992) suggest that size may be analyzed separately from shape during object recognition. The shape-based representation most critical for naming retains visual characteristics specific to a particular object.

Stimulus realism. Pictures vary in the extent to which they realistically depict objects. Such details as color, texture, and brightness contribute to the dimension of stimulus realism, which ranges from detailed colored photographs to simple outline drawings. A key unresolved theoretical issue concerns the extent to which such surface details play a central role in object recognition (e.g., Biederman, 1987; Davidoff, 1991; Marr, 1982).

Research on stimulus realism has yielded conflicting results. In some cases, realistic stimuli (e.g., objects, photographs, and colored drawings) were identified or named faster or more accurately than less realistic depictions of the same objects (Benton, Smith, & Lang, 1972; Bisiach, 1966; Loftus & Bell, 1975; Nelson, 1972; Ryan & Schwartz, 1956; Shuttleworth & Huber, 1988; Stevens, 1989). In other cases, stimuli that varied in realism did not differ in identification or naming efficiency (Corlew & Nation, 1975; Hatfield, Howard, Barber, Jones, & Morton, 1977; Mial, Smith, Doherty, & Smith, 1974; Towne & Banick, 1989). Still other reports suggest that effects of stimulus realism may depend on task conditions (Biederman & Ju, 1988; Davidoff & Ostergaard, 1988; Johnson, 1992, 1995; Ostergaard & Davidoff, 1985; Price & Humphreys, 1989). In particular, stimulus realism may augment picture identification when global-shape information is insufficient, for example, when distinct objects are similar in overall shape (Nelson, 1972; Price & Humphreys, 1989) or when real objects must be discriminated from nonobjects that resemble them in global characteristics (Johnson, 1992).

Current understanding of the effects of stimulus realism on naming is limited by the perceptual complexity of the dimension, the lack of an accepted metric for measuring realism (Levie, 1987), and the narrow range over which realism has generally been varied (e.g., comparisons of real objects with fairly detailed line drawings). Future research would benefit from inclusion of stimuli from the full range of the realism dimension, as well as orthogonal separation of the effects of color and other surface details (e.g., Price & Humphreys, 1989).

Color may need to be considered separately because it appears not to be an inherent characteristic of long-term object representations. Instead, memory information about object color may be associatively connected to both object representations and corresponding name representations (Davidoff, 1991; Paivio, 1978). Two key pieces of supporting evidence are that adults find object color information equally accessible from both pictures and words in symbolic comparison tasks (Paivio & te Linde, 1980) and that young children retrieve object color more readily from word than from picture cues (Davidoff & Mitchell, 1993). Nonverbal associations are also suggested by detrimental effects of incongruent color (e.g., a blue apple) on naming and identification (Johnson, 1995; Price & Humphreys, 1989), at least when the numbers of stimuli are large and the incongruent colors are not known in advance. With advance knowledge and blocked presentation of incongruent stimuli, participants may be able to ignore incongruent color (Johnson, 1995; Ostergaard & Davidoff, 1985; but see Mial et al., 1974), further suggesting that color is an associated property rather than an intrinsic aspect of object representations. Moreover, these ideas accord with other psychological results (e.g., Treisman & Gelade, 1980) and neuroanatomical and neurophysiological evidence (Livingstone & Hubel, 1988) that implicate simultaneous and relatively independent early visual processing of object color and shape. Missing, however, is a

plausible account of how and when color and shape information come together during object identification.

Further studies could attempt to verify effects of color on object identification and naming by investigating the congruency of object memory colors as a graded attribute (e.g., apples in red, green, and blue; cf. Paivio & te Linde, 1980). Also relevant would be priming experiments that involve consistent or inconsistent colors across prime and target pictures or that assess the combined effects on object naming of priming with colors and color names.

Stimulus complexity. The effects of stimulus complexity on object identification and naming have received surprisingly little study, perhaps in part because there is no accepted metric for complexity (Levie, 1987). Some options include the number of object parts (Biederman, 1987), the number of pixels in a computerized image (Snodgrass & Corwin, 1988), and participant ratings of object or picture complexity (Berman, Friedman, Hamberger, & Snodgrass, 1989; Paivio et al., 1989; Snodgrass & Vanderwart, 1980). Variations in complexity across pictures of different objects have little effect on identification or naming RTs (Biederman, 1987; Paivio et al., 1989; Snodgrass & Corwin, 1988); that is, complex objects are identified and named as readily as simple objects. This somewhat counterintuitive result has yet to be fully investigated or explained. It is, however, consistent with dual coding and other views that posit simultaneous, parallel activation of holistic, object-specific representations. Such parallel processes may be little influenced by complexity. The similarity among objects within a task may also determine the specific discriminations required to identify a particular object (e.g., Humphreys et al., 1988). Obviously, issues concerning picture complexity overlap with those concerning stimulus realism and perhaps size.

Stimulus familiarity. Ratings of the familiarity of various objects contribute little unique variance to prediction of item differences in picture naming RTs (Paivio et al., 1989), in part because of high correlations with word familiarity (see *Word frequency* below). Later, we see (in the *Practice* section), however, that picture familiarity has larger effects on various stages of naming when it is experimentally manipulated.

Canonical perspective. Adults have a preferred (canonical) perspective from which to view a given object. This canonical viewpoint maximizes available information concerning the object's identity (e.g., salient parts, relations between parts, and surface and depth cues) and corresponds to adults' spontaneously generated images of the object. Naming is fastest when an object is depicted from its canonical viewpoint, as compared with other possible views (Palmer, Rosch, & Chase, 1980).

Effects of picture–image similarity and object orientation on naming further support an influence of canonical perspective on object identification. Paivio et al. (1989) asked participants to generate an image for each of a series of object names and then to rate how similar each image was to a picture with the same name. Pictures given high similarity ratings were named quickly by another group of participants. Because images were presumably generated from long-term object representations, this suggests that canonical perspective may be an inherent quality of such representations. Object orientation also affects naming RTs (Jolicoeur, 1985, 1988; Jolicoeur & Milliken, 1989), with upright objects (i.e., canonical orientation) named more quickly than objects shown in other (noncanonical) orientations. The initial representation of a disoriented stimulus may be normalized to upright through mental rotation before matching it with its long-term representation (Jolicoeur, 1985, 1988). Mental rotation is a transformational strategy that can be applied holistically to object images, as assumed in dual coding and other theories that emphasize modality specific representations.

Modality. In the dual coding view, an object representation comprises memory traces corresponding to the various sensory modalities (e.g., vision, touch, and audition) in which an object is experienced. Although often integrated in experience, these modality-specific traces may function independently, additively contributing to cognitive performance (e.g., V. Thompson & Paivio, 1994). Moreover, an experience in one modality (e.g., smelling a pizza) often redintegrates object memories specific to other modalities (e.g., taste, sight, and feel).

Evidence from naming tasks also implicates multimodal object representations. Object naming often primarily relies on visual characteristics but can also be based on auditory or tactile characteristics (Buckingham, 1981; Goodglass, 1980; V. Thompson & Paivio, 1994). Further evidence for the separability of various modalities comes from the modality-specific (i.e., visual, tactile, and auditory) object recognition deficits experienced by some individuals with neurological impairments (Beauvois, Saillant, Meininger, & Lhermitte, 1978; Behrmann, Moscovitch, & Winocur, 1994; Denes & Semenza, 1975; Ratcliff & Newcombe, 1982; Spreen, Benton, & Van Allen, 1966). These people cannot recognize or name objects presented in a particular modality but can recognize and name the same objects presented in unaffected modalities. Naming may also be influenced by operativity, the rated extent to which an object can be experienced in several modalities (H. Gardner, 1973, 1974). For example, a telephone, which can be seen, heard, touched, and manipulated, could be named more readily than a cloud, which can be seen but not heard, touched, or manipulated. Further evidence is needed, however, because rated operativity is confounded with other correlated attributes that may influence naming (Feyereisen, Van der Borght, & Seron, 1988).

Thus far, possible modality effects on naming have usually been studied in adults with neurological impairments, using case study and correlational methods. Future work might use both participants without impairments and experimental methods. For example, naming could be compared for novel object–name pairs learned under different modality conditions. Such experiments may provide further evidence on the nature of modality-specific representations and on multiple routes to object identification and naming (Allport, 1985). To the extent that modality-specific effects could be attributed to the characteristics of long-term memory representations, amodal models would be undermined.

Summary: Object identification and stimulus attributes. Cognitive theorists generally agree that picture naming begins with rapid, visual extraction of modality-specific information on object shape and component parts. Disagreement centers on whether activation of such a modality-specific representation is sufficient for object identification, as proposed by dual coding theory, or merely initiates contact with an amodal representation of the corresponding concept, activation of which corre-

sponds to object identification. We return to this issue later, but note that we have already reviewed evidence for the involvement of modality-specific representations in object identification and have found no direct evidence suggesting a functional role for an amodal representation in either object identification or picture naming.

Name Activation by Way of Referential Processing

Dual coding theory assumes that referential connections directly link object and name representations in a one-to-many fashion (e.g., an object representation for a tricycle is linked directly to various name representations: *tricycle, bicycle, trike, bike, toy*, and *vehicle*). In contrast, amodal representational theories assume an indirect linkage of object and name representations through one or more abstract conceptual representations. In this section, we review effects on naming of item attributes that reflect referential relations between objects or pictures and their names, looking specifically for effects that implicate an indirect referential process.

Uncertainty. An attribute that reflects the multiplicity, strength, or both of referential relations is linguistic codability or uncertainty (Lachman, 1973a, 1973b; Lachman & Lachman, 1980; Lachman et al., 1974). Various operational definitions of uncertainty (e.g., Paivio et al., 1989; Snodgrass & Vanderwart, 1980) tap either the number of connections between an object and its names (e.g., number of different names for a picture across participants), the relative strength or dominance of individual connections (e.g., proportion of participants giving the dominant name), or both (e.g., the uncertainty statistic, H). The relative influences on naming of these two theoretically distinct, but highly correlated, aspects of referential relations (number and strength of connections) have not yet been disentangled. The various uncertainty measures also best operationalize referential relations when both omission and commission errors attributable to object misidentification are minimized (Johnson, 1992), but this practice has not been consistently followed. A further definitional complexity is that uncertainty estimates for a given picture may vary as a function of developmental level (Berman et al., 1989; Butterfield & Butterfield, 1977; Cirrin, 1983; Johnson & Clark, 1988) and, perhaps, individual differences (Goggin, Estrada, & Villarreal, 1994), presumably reflecting variations in relevant nonverbal and verbal knowledge.

Uncertainty is a robust predictor of naming difficulty. Pictures with a single dominant response are named more quickly and accurately than those with multiple possible responses (Butterfield & Butterfield, 1977; Johnson & Clark, 1988; Lachman, 1973a; Lachman & Lachman, 1980; Lorsbach & Morris, 1991; Mitchell, 1989). Uncertainty affects naming independent of the effects of correlated attributes, such as word frequency and rated age of name acquisition (Cirrin, 1983; Gilhooly & Gilhooly, 1979; Johnson, 1992; Lachman, 1973b; Lachman et al., 1974; Paivio et al., 1989).

Uncertainty may increase naming RTs because spreading activation is diffused along multiple object–name pathways or because a response is delayed until competing names are inhibited (Paivio et al., 1989). Name competition may be especially problematic for children (Clark & Johnson, 1994; Johnson, 1994; Johnson & Clark, 1988; Lorsbach & Morris, 1991) and others who are not skilled in naming, such as adults with aphasia (Mills, Knox, Juola, & Salmon, 1979), perhaps because inhibitory processes are inefficient. Practice may lessen name competition, as high-uncertainty pictures show more facilitation on a second naming than do low-uncertainty pictures (Lorsbach & Morris, 1991; Mitchell, 1989), but the contributions of excitation and inhibition to such practice effects remain to be determined. The interaction of practice and uncertainty could also reflect a floor effect for low-uncertainty items.

Lachman and Lachman (1980) proposed a name activation locus for uncertainty because it does not influence the speed of picture–picture and name–picture matching. This argument assumes that matching and naming involve similar object-identification processes. In fact, matching may require less perceptual processing than naming because picture characteristics can be anticipated from a prior presentation of a picture (C. Warren & Morton, 1982) or a name (Reinitz, Wright, & Loftus, 1989). Johnson (1992) obtained stronger evidence for a postidentification locus by comparing uncertainty effects in naming and object decision (Kroll & Potter, 1984), a task in which picture characteristics cannot be anticipated. Uncertainty increased naming but not object-decision RTs for the same pictures, suggesting that it affected a postidentification stage unique to naming (name activation, response generation, or both). An experimental manipulation of uncertainty confirmed a postidentification locus. Participants learned novel object–name pairs to criterion and then named pictures of the novel objects in an RT task. Intrinsic differences in the ease of object identification were eliminated by counterbalancing the assignment of novel objects to uncertainty conditions (one vs. two names per object), but novel objects with two names were still named slower than those with one name. This experimental finding strengthens the argument that uncertainty effects represent the influence of multiple object–name links, over and above the influences of other attributes that increase naming difficulty.

Goals for future research include more precise specification of the loci (name activation, response generation, or both) and mechanisms (passive diffusion, active inhibition, or both) responsible for referential uncertainty effects. Independent manipulations of the number and strength of possible names are essential in this regard.

Current findings on the robust effects of uncertainty do not require the assumption of indirect object–name connections by way of amodal conceptual representations. The extra links are unnecessary. To support their model, amodal theorists would need to demonstrate independent effects on naming of uncertainty for image–concept links and for concept–name links.

Pictures compared with other nameable stimuli. Adults name pictures or colors slower than they read the names for those same pictures or colors (W. Brown, 1915; Cattell, 1886; Fraisse, 1960, 1964, 1967, 1968, 1969; Irwin & Lupker, 1983; Jolicoeur, Gluck, & Kosslyn, 1984; Ligon, 1932; Potter & Faulconer, 1975; Theios & Amrhein, 1989). The dual coding account of this difference is straightforward. Picture and color naming require a nonverbal-to-verbal translation step, which is not required in word naming (Paivio, 1986). Amodal theories generally account for this difference by assuming that words can be named without concept access, whereas pictures require it

(Theios & Amrhein, 1989), thereby rendering the amodal account of the naming–reading difference indistinguishable from the dual coding explanation (Paivio, 1986). Moreover, words are associated with a single response name, but pictures or colors may be linked to several names (Fraisse, 1969; Paivio, 1986; Theios & Amrhein, 1989). Thus, the greater uncertainty (see *Uncertainty*) of pictures or colors than of words may contribute to the naming–reading difference.

The view that structural aspects of referential connections underlie picture–word and color–word differences is reinforced by evidence that such differences are not reduced substantially by development (Ligon, 1932) or extensive practice (W. Brown, 1915; Fraisse, 1964, 1969). Moreover, visual analysis is not the source of picture–word differences because visual matching of picture–picture or word–word pairs takes a similar amount of time if stimulus sizes are equated (Theios & Amrhein, 1989; but see Glaser, 1992).

Picture–word differences in naming have not discriminated the dual coding and abstract coding views (Paivio, 1986; Snodgrass, 1984). Theios and Amrhein (1989), however, argued that picture–word differences on a comparison task could be used to test the two models. Participants judged whether pairs of same-modality stimuli (picture–picture or word–word) and cross-modality stimuli (picture–word or word–picture) represented the same or a different concept. The crucial prediction concerned different judgments. By an amodal account, same-modality and cross-modality different judgments should take equal time because both stimuli are translated to an amodal version before comparison. Theios and Amrhein suggested that, by a dual coding account, same-modality different judgments should take less time than cross-modality judgments because in the latter case the second stimulus is translated into the modality of the first stimulus before comparison. From our viewpoint, it would be important to obtain converging evidence that participants actually adopt the translation strategy proposed by Theios and Amrhein. Even granting this assumption, however, the evidence is inconclusive.

The critical time difference was in the direction predicted from the dual coding interpretation assumed by Theios and Amrhein (1989) but was not significant by their conservative statistical criterion ($p < .01$). They, therefore, concluded in favor of an amodal account, effectively accepting the null hypothesis for $p = .03$. They also developed a formal predictive model that showed a good fit to the data from both naming and comparison tasks, but they did not demonstrate that eliminating the amodal component from their model led to a poorer fit to the data. Thus, the support claimed for an amodal model is equivocal, at best.

Generality. An object can be named at various levels of generality (R. Brown, 1958). For example, the same object can be named at the subordinate (recliner), basic (chair), or superordinate (furniture) levels (Rosch et al., 1976). Most names used by adults, particularly in speaking to children, refer to objects at an intermediate (basic) level of generality (Anglin, 1977; Wales, Colman, & Pattison, 1983; White, 1982). Thus, children usually learn basic level names before superordinate and subordinate names (Anglin, 1977; Markman, 1989; Nelson, 1985; Rosch et al., 1976).

The generality of object–name relations affects naming performance. Basic level names usually are given faster than superordinate names (Clark & Johnson, 1994; Irwin & Lupker, 1983; Jolicoeur et al., 1984; Smith & Magee, 1980; Wingfield, 1967) or subordinate names (Jolicoeur et al., 1984; Seymour, 1973). Objects may be identified, not just named, faster at the basic level because members of these categories share more distinctive attributes than do members of superordinate or subordinate categories (Mervis & Crisafi, 1982; Rosch et al., 1976). Interpretation of the basic level advantage for natural language stimuli, however, is complicated because the generality of object–name relations is confounded with other relevant variables, such as separate and joint experience with the relevant object categories and their names, order of learning, name frequency, and name length. G. Murphy and Smith (1982) systematically controlled many of these variables in artificial-category–name-learning tasks and found an identification advantage for categories that shared perceptual features, even when such categories were superordinate in nature. The relative availability of superordinate and basic level names could also vary with the frequency and recency of presentation of category members, perhaps reversing the usual advantage for basic level naming.

Jolicoeur et al. (1984) concluded that the additional time required for superordinate, relative to basic level, naming reflects primarily postidentification processes. For example, production of superordinate names may be slowed by the need to inhibit more readily available basic level names (Clark & Johnson, 1994; Johnson & Clark, 1988). A similar inhibitory process may add to the time required for subordinate, as compared with basic level, naming (Seymour, 1973). In addition, subordinate naming apparently requires more extensive perceptual processing of the stimulus than does basic level naming (Jolicoeur et al., 1984). However, objects that are atypical members of their respective categories may be named more readily at the subordinate level than at the basic level (Brownell, Bihrle, & Michelow, 1986; Jolicoeur et al., 1984), suggesting that the idea of basic level categories may have limited theoretical value. Jolicoeur et al. proposed instead that identification is based on object-specific representations, an idea compatible with the dual coding view.

Generality issues, particularly those dealing with superordinate categories, have been a testing ground for dual coding and amodal theories. Unfortunately, many tests reported in the literature were based on incomplete or incorrect interpretations of the dual coding position (Paivio, 1983, 1986, 1991). The dual coding view is that superordinate information is multiply represented in both the nonverbal and verbal subsystems (Paivio, 1971, pp. 287, 529–530; Paivio, 1986, pp. 131–132). For example, superordinate information about an apple might be represented by a direct referential connection from an imagen for *apple* to the name *fruit* or by mediated links from the imagen to the name *apple* and then *fruit*. Superordinate information could also be conveyed by nonverbal associations between imagens for *apple* and other members of the *fruit* category acquired through their co-occurrence in bowls of fruit, fruit markets, and other relevant experiences. Verbal associative links would be similarly acquired between the words *apple, banana, pear*, and so on, all of which would share associations with the category word *fruit*. The dual coding analysis also suggests that

many objects (e.g., key and pencil) do not have a particularly rich set of superordinate representations. In either case, the nature of the activated superordinate information would be determined by specific stimulus, task, and participant variables that are amenable to empirical investigation.

Evidence that pictures are categorized faster than words has been interpreted as inconsistent with dual coding because it has been assumed erroneously that superordinate information is necessarily abstract and, therefore, represented only verbally according to dual coding (e.g., Glaser, 1992; Potter & Faulconer, 1975). Despite reiteration of the dual coding view (Paivio, 1983, 1986, 1991) and compelling evidence that superordinate categorization often depends on perceptual characteristics of pictured objects (Flores d'Arcais & Schreuder, 1987; Job, Rumiati, & Lotto, 1992; G. Murphy & Smith, 1982; Snodgrass & McCullough, 1986), this incorrect interpretation persists.

Pellegrino, Rosinski, Chiesi, and Siegel (1977) also claimed results inconsistent with dual coding. They compared predictions from a dual code model with superordinate information in both subsystems with those from a single-store model (similar to amodal) and from a dual code model with superordinate information only in the verbal subsystem. Participants judged the superordinate category membership (same–different) of picture–picture, picture–word, word–picture, and word–word pairs or judged the real-world size of objects represented by single pictures and words, a task thought to tap the nonverbal subsystem (Paivio, 1975). Pictures showed a similar advantage in both tasks, suggesting that both engaged a single representational subsystem. The test, however, is not definitive with respect to the dual coding model of superordinate representation because only categories with high levels of perceptual and functional similarity were tested (animals and clothes). Thus, both size and category judgments may have been mediated by the nonverbal subsystem. The general approach taken by Pellegrino et al. could, perhaps, be extended to include category judgments that are more likely to be mediated verbally.

Certain amodal models postulate two levels of hierarchically related conceptual nodes that represent an object's basic and superordinate category membership, respectively (Glaser & Glaser, 1989; Roelofs, 1992). A superordinate concept node is accessed only through prior access to its basic node. Basic names are activated by basic concept nodes; superordinate names are activated only through superordinate concept nodes by way of basic concept nodes.

A possible inference from these amodal serial-stage accounts is that superordinate naming should always be slower than basic level naming because superordinate naming requires an additional processing step. This claim is not universally true, as demonstrated by stimuli for which basic level naming is slower than superordinate naming (e.g., *asparagus*). Such findings are consistent with the dual coding view that imagens can have direct links to basic and superordinate names. Amodal models can be salvaged by either relaxing the assumption that superordinate concepts can only be accessed through basic level concepts or by postulating varied strengths for the different connections and representations; for example, the basic name representation for *asparagus* may be sufficiently unavailable to offset the extra steps to the more available superordinate name *vegetable*. These are exactly the assumptions made by dual coding theory, albeit without the extra assumption of abstract codes. The dual coding account, which permits direct connections between object and superordinate name representations rather than only indirect connections through superordinate concepts, suggests that superordinate names sometimes could be produced as quickly or even more quickly than basic level names because naming speed primarily reflects the relative strength of object–name connections, as determined by prior relevant experiences. Artificial-category–name-learning tasks (e.g., G. Murphy & Smith, 1982) may be useful in pursuing these issues.

Other data troublesome for amodal theories were reported by Morrison et al. (1992). They reasoned from an amodal view that picture categorization (man-made vs. natural) and picture naming should require similar visual analysis and semantic access stages and that category prototypicality should influence at least one of these stages (Seymour, 1976). Prototypicality influenced categorization but not naming, which led Morrison et al. to suggest that an object's semantic representation may not contain information on whether it is man-made or natural. This conclusion, however, is at odds with most descriptions by amodal theorists of the types of information (e.g., properties, attributes, and functions) available from an object's semantic representation. An alternative explanation, consistent with dual coding, is that categorization may be based not only on the initial object representation required for naming but also on subsequent associative or referential activity.

Careful theoretical and empirical work on generality issues is needed to sort out the complex influences of stimulus, task, and participant factors. A key distinction is between determining an object category and producing an object category name (Markman, 1989). On a dual coding view, category naming of pictures necessitates referential processing and subsequent activation of the verbal subsystem, whereas categorizing of pictures may not.

Summary: Referential processing and referential attributes. In our survey of referential attributes, we have not uncovered compelling evidence that amodal conceptual representations mediate picture naming. Existing findings can be explained by the dual coding assumptions of modality-specific object representations, associative links to other object representations, and referential links to object names. Stronger tests of the amodal and dual coding accounts await further elaboration and clarification of expected distinctions between them. It is particularly critical that amodal theorists specify the nature of information that becomes available from an amodal concept representation that is not available from an earlier visual representation of the object and its associates or from later verbal representations of the object's various names.

Name Activation and Response Generation

During naming, referential connections permit activation of auditory–motor word representations that are probably distinct from the visual word representations activated directly during reading. A word is selected for production when its activation exceeds a threshold level. Production occurs sequentially, that is, sounds in the name are produced in a particular order. Below,

we consider several word attributes that may affect the name activation stage, response generation stage, or both.

Word frequency. Oldfield and Wingfield (1964, 1965) reasoned that naming RTs for pictures should be related to the familiarity of the object and its name, as estimated by the frequency with which the name word appears in print. As expected, high-frequency names were given as responses more quickly and accurately than low-frequency names. This word frequency effect has been replicated often (Bartram, 1974; Fried-Oken, 1984; German, 1979, 1984; Goodglass, Theurkauf, & Wingfield, 1984; Leonard, Nippold, Kail, & Hale, 1983; Milianti & Cullinan, 1974; Newcombe, Oldfield, Ratcliff, & Wingfield, 1971; Newcombe, Oldfield, & Wingfield, 1965; Rochford, 1971; Rochford & Williams, 1963, 1965; Rudel, Denckla, & Broman, 1981; Thomas, Fozard, & Waugh, 1977; Vitkovitch & Humphreys, 1991; Williams & Canter, 1982). With practice, low-frequency items may show a greater reduction in RTs than high-frequency items (Bartram, 1973), thereby reducing the frequency effect, but this result is not always found (Jescheniak & Levelt, 1994). Discrepant results may reflect differences across studies in the amount of practice or in the extent of frequency differences between items. Practice effects for high-frequency items could also be limited by floor effects, that is, some high-frequency items may already be named so quickly that further practice cannot improve naming speed substantially.

Although word frequency has a robust effect on naming RTs, it does not influence picture-identification thresholds or name–picture-matching speeds (Jescheniak & Levelt, 1994; Milianti & Cullinan, 1974; Thomas et al., 1977; Wingfield, 1968). Such findings suggest that word frequency has its primary effect during postidentification stages of naming (Oldfield, 1966). That word frequency does not interact with variables assumed to affect object identification provides further support for a post-identification locus (Henderson et al., 1987; Huttenlocher & Kubicek, 1983; but see Humphreys et al., 1988, for a contrary result). Several studies suggest that response articulation is not the locus of the word frequency effect (Jescheniak & Levelt, 1994; Wheeldon & Monsell, 1992).

Further evidence, however, is needed to bolster conclusions based on correlational findings. Word frequency is an item attribute that has usually been studied in correlational designs in picture-naming research. Thus, it is impossible to know whether an effect is attributable to word frequency or to another variable that is confounded with frequency. This problem is particularly acute when major theoretical conclusions are based on correlational evidence. For example, Humphreys et al. (1988) interpreted an interaction between word frequency and structural similarity as evidence for a cascade model of picture naming, in which information flows continuously from one stage to the next. However, both word frequency and structural similarity were correlational variables, making it unclear whether they were responsible for the effects.

Moreover, printed word frequency may not be the most appropriate way to operationalize the extent to which words are available for use as picture-naming responses. Spoken word frequency or rated word familiarity, which are correlated with printed frequency (Paivio et al., 1989), may be more conceptually appropriate measures.

Age of acquisition. J. B. Carroll and White (1973a, 1973b) argued that the age at which a word is normally acquired (age of acquisition or Age A) provides a better estimate of overall word familiarity (both spoken and written) than printed frequency. They demonstrated, as have others (Feyereisen et al., 1988; Gilhooly & Gilhooly, 1979; Johnson & Clark, 1988; Morrison et al., 1992; Paivio et al., 1989), that words learned earlier in life are given more quickly and accurately as naming responses than words learned at a later age and that rated Age A is a better predictor of naming RTs than printed word frequency. Age A ratings probably reflect multiple dimensions, as suggested in a comprehensive factor analysis of attributes predictive of naming RTs, which showed Age A variance to be distributed across factors representing concreteness, word familiarity, and word length (Paivio et al., 1989). The validity of Age A ratings is supported by strong correlations (rs = .54–.93) with objective indices of word-acquisition age (J. B. Carroll & White, 1973a, 1973b; Gilhooly & Gilhooly, 1980; Johnson & Clark, 1988; Lyons, Teer, & Rubenstein, 1978; Walley & Metsala, 1992).

Morrison et al. (1992) argued that Age A affects name activation because it influences RTs for picture naming but not picture categorization (man-made vs. natural objects). They proposed that names learned earlier in life may have stronger links to object representations or that Age A may be an intrinsic attribute of name representations. Again, such ideas should be evaluated cautiously because Age A effects have been studied only in correlational designs.

Word length. Naming becomes more difficult with increases in word length, as measured by number of syllables or phonemes (R. B. Katz, 1986; Klapp, Anderson, & Berrian, 1973; Tweedy & Schulman, 1982). Clear interpretation of such effects requires unconfounding the usual correlation between length in syllables and length in phonemes (Marmurek & Rinaldo, 1992). Word length effects are at least partly independent of effects attributable to word frequency and rated Age A (Morrison et al., 1992; Paivio et al., 1989).

Logically, word length affects the name activation stage, response generation stage, or both. Klapp et al. (1973) argued for localization at response generation because number of syllables increased picture-naming RTs but not RTs to complete a picture–word comparison task that did not require overt verbal responses. In addition, syllable effects were not evident when participants had ample time to prepare a naming response before pronouncing it (see also Marmurek & Rinaldo, 1992). Levelt (1989, ch. 11) suggested that the length effect arises primarily during assembly of the phonetic program for a verbal response, the first of his four hypothesized substages of response generation. He attributed additional effects of word length to later substages of retrieving the program from a temporary storage buffer and unpacking it before its execution as motor commands. Levelt acknowledged, however, that buffering and unpacking substages may be more essential in conversational utterances than in single picture-naming responses. Word length could be readily manipulated in novel object–name pairings to further clarify possible loci of its effects.

Summary: Postidentification stages and word attributes. Various word attributes apparently affect postidentification stages of naming, but it remains to be determined whether the

influences arise at the name activation stage, response generation stage, or both. Because dual coding and most four-stage amodal models make similar, quite general assumptions about the interface between name activation and response generation, the existing evidence can be accommodated by either class of model. That is, amodal codes are not necessary to explain present results.

Levelt (1989) provided a more detailed treatment of name activation and response generation, which raises issues that have been relatively neglected by other naming models. For example, when and how in the naming sequence is a name selected? Are names represented in units that correspond to words, syllables, or phonemes, or to some other possibility (Butterworth, 1983, 1989; Lupker, 1985; G. A. Miller, 1991)? If units are smaller than words, how are they assembled to produce a name response? Are motor planning and articulatory execution separate substages of response generation? Limitations of space preclude a detailed evaluation of the speech error data and other evidence that Levelt marshaled to support his proposals. We note simply that the evidence did not appear to require abstract, conceptual representations or necessitate his assumption that word representations are abstract. Methods that may yield further information on name activation and response generation include comparisons across covert and overt response conditions, variations of response preparation time, and experimental manipulations of word attributes.

Effects of Task Conditions on Naming Stages

Both practice and context manipulations, reviewed next, appear to affect multiple stages of naming. We explicitly highlight dual coding interpretations in instances where theoretically relevant variables have been manipulated or are clearly implicated. Otherwise, the dual coding analysis remains implicit.

Practice

Practice reliably reduces naming RTs (Bartram, 1973, 1974; Biederman & Cooper, 1991a, 1991b; Biggs & Marmurek, 1990; Durso & Johnson, 1979; Fried-Oken, 1984; Jescheniak & Levelt, 1994; Lachman & Lachman, 1980; Lachman et al., 1974; Lorsbach & Morris, 1991; Lorsbach, Sodoro, & Brown, 1992; Milianti & Cullinan, 1974; Mills et al., 1979; Rochford & Williams, 1963; Snodgrass & Hirshman, 1994). Practice induces both generalized facilitation, which may reflect speedup in overt response generation (A. S. Brown et al., 1991), and item-specific facilitation, often termed "repetition priming." The latter facilitation in naming RTs for previously named pictures is remarkably persistent, lasting up to 6 weeks, even though many of the pictures are no longer recognized in an explicit memory test (Mitchell & Brown, 1988). Repetition priming also occurs in other cognitive tasks that require picture or word processing (but see Biederman & Cooper, 1992, for evidence that repetition priming in naming may not be equivalent to that obtained in name-identity judgment or recognition-memory tasks). The phenomenon has taken a prominent place in memory research and theorizing (for reviews, see Richardson-Klavehn & Bjork, 1988; and Schacter, Chiu, & Ochsner, 1993) because it may not depend on conscious awareness of prior item processing or reflect the processes tapped by such traditional memory tasks as recognition and recall.

Most evidence suggests that repetition priming arises at both identification and postidentification stages of picture naming (Schacter, Delaney, & Merikle, 1990). Maximal facilitation in RT occurs when the same picture is renamed (Bartram, 1974; Lachman & Lachman, 1980), but some facilitation also occurs for a different picture that requires the same name response (Bartram, 1974; Biederman & Cooper, 1991a, 1991b, 1992). Some facilitation also results from prior exposure to the picture even without explicit naming (M. Carroll et al., 1985; Lachman & Lachman, 1980) or from prior production of the name word not in response to a picture (Durso & Johnson, 1979; Lachman & Lachman, 1980; Monsell, Matthews, & Miller, 1992; Wheeldon & Monsell, 1992), again implicating contributions from identification and postidentification stages, respectively.

The amount of repetition priming attributable to identification processes appears unaffected by changes in picture size (Biederman & Cooper, 1992), retinal position, and left–right orientation (Biederman & Cooper, 1991a; see Cooper, Schacter, Ballesteros, & Moore, 1992, for similar results from object-decision tasks). Apparently, repetition priming arises at least in part from a shape-based, object-specific representation that retains a partial, but not complete, correspondence with the perceptual characteristics of the stimulus picture (see earlier sections on *Canonical perspective* and *Stimulus size*). Such object-specific representations appear more consistent with dual coding imagens than with amodal abstract concepts.

That activation of a name representation, rather than articulation per se, is the postidentification priming locus is suggested by (a) equivalent amounts of facilitation following covert and overt naming practice (A. S. Brown et al., 1991); (b) lack of priming from production of a homophonic word identical in sound form to the picture name but having a different meaning (Wheeldon & Monsell, 1992); and (c) priming from word meaning, listening, or reading tasks that did not involve overt production (A. S. Brown et al., 1991; Ferrand, Grainger, & Segui, 1994; Lorsbach et al., 1992). Reported interactions between practice and word frequency (e.g., Bartram, 1973) suggest that repetition priming may be the learning mechanism underlying word frequency effects in naming (Wheeldon & Monsell, 1992).

Context

Immediate context also affects picture-naming performance. Both the direction (facilitation or interference) and the degree of context effects are determined by complex interactions among stimulus and task conditions. Much of the available research has been focused on the effects of semantic similarity between context stimuli (pictures or words) and target pictures. Unfortunately, semantically related items (e.g., apple and orange) may share visual characteristics, strong associative (nonverbal, verbal, or both) relations, or membership in the same superordinate category. The unconfounding of these various relations is critical for distinguishing between a dual coding model, in which associative relations are central, and various amodal models that posit abstract categorical relations (see *Generality*). As seen later, much of this important work re-

mains to be done. Where possible, we attribute relevant effects to visual, associative, or categorical relations, or combinations thereof; in most cases, however, the operative aspects underlying so-called semantic effects are not yet known. We first discuss facilitation attributable to picture and word context stimuli and then consider interference.

Picture naming can be primed by a prior presentation of a nonverbal or verbal stimulus that is related semantically to the target picture. Effective primes include a semantically related picture (Bajo, 1988; Biggs & Marmurek, 1990; Carr, McCauley, Sperber, & Parmalee, 1982; Flores d'Arcais & Schreuder, 1987; Henderson et al., 1987; Huttenlocher & Kubicek, 1983; Lupker, 1988; McCauley et al., 1980; McCauley, Weil, & Sperber, 1976; Pollatsek, Rayner, & Collins, 1984; Sperber et al., 1979), meaningful scene context (Boyce & Pollatsek, 1992), semantically related word (Bajo, 1988; Carr et al., 1982; Lupker, 1988; Sperber et al., 1979), superordinate category name (Ceci, 1983; Kareev, 1982; Sperber, Davies, Merrill, & McCauley, 1982), or meaningful sentence context (Barton, Maruszewski, & Urrea, 1969; Kail & Leonard, 1986; Potter, Kroll, Yachzel, Carpenter, & Sherman, 1986; Rudel et al., 1981; Rudel, Denckla, Broman, & Hirsch, 1980). Picture naming can also be primed by a prior reading or production of a word that shares phonological characteristics with the target name (Ferrand et al., 1994; Lupker & Williams, 1989; McEvoy, 1988).

Some priming may result from repetition of cognitive operations during prime and target processing, but most priming is usually attributed to activation that automatically spreads from the object representation, name representation, or both of the prime to those of a related target, thereby facilitating later target processing. Dual coding suggests that activation could spread by way of within-system (verbal and nonverbal) associations and between-system referential links.

Picture–picture priming apparently originates before name activation, thus primarily within the nonverbal subsystem, as evidenced by its facilitation of picture-recognition performance (Henderson et al., 1987; C. Warren & Morton, 1982), its effectiveness at very brief prime exposure durations (i.e., before primes can be identified or named; McCauley et al., 1980), and its operation even in simultaneous presentation of prime and target pictures (Allport, Tipper, & Chmiel, 1985; Henderson, 1992). Possible, albeit inconclusive, converging evidence for an identification locus of picture–picture priming comes from experiments using additive factors logic. For example, picture–picture priming shows additivity with word frequency, which may affect name activation (Huttenlocher & Kubicek, 1983; see also *Word frequency*), and interacts with stimulus quality, which presumably affects object identification (Sperber et al., 1979; see also *Stimulus quality*). Picture–picture priming might also facilitate object identification through an indirect route involving referential activation of a name for the prime picture, verbal associative activation of a name for a related picture, and referential activation of an image for that picture. This indirect route could also facilitate the name activation stage and might be used most often when the presentation intervals between primes and targets are relatively long or when both pictures and words are used in a priming experiment.

Visual and associative–categorical similarity between prime–target picture pairs have separate priming effects on picture naming (Flores d'Arcais & Schreuder, 1987; Sperber et al., 1979), as evidenced by priming from visual similarity in the absence of associative–categorical similarity (Pollatsek et al., 1984) and from associative–categorical similarity with visual similarity controlled (Huttenlocher & Kubicek, 1983). In dual coding terms, separate representational level and associative processes may be primarily responsible for these effects: repetition of encoding operations in the case of visually based priming and spread of activation by way of associative connections between object representations in the case of associative–categorical priming. Consideration of these and other processes may also explain findings that seem inconsistent with the dual coding view. Lupker (1988, Experiment 1), for example, reported that categorical relations between prime and target pictures facilitated picture naming in the relative absence of associative relations. The category effect was relatively small and significant over participants but not items. The facilitating effect may have arisen from visual similarity among some of the same-category pictures, which was not controlled. Moreover, the requirement to name the prime picture may have initiated verbal associative priming, thereby facilitating activation or production of the target name, subsequent referential facilitation of object identification through imagery, or both.

The situation is equally complex in the case of word–picture semantic priming. The main locus of such priming appears to be the same as that for picture–picture priming (Carr et al., 1982; Lupker, 1988; Sperber et al., 1979, 1982); that is, in dual coding terms, word–picture priming implies initial referential activation spreading from the prime word to an imaginal representation for the prime's referent, followed by associative activity within the nonverbal subsystem. Interpretations are uncertain because the amount of facilitation arising from related word primes is more variable across experiments than that arising from corresponding picture primes (Glaser, 1992). Word–picture priming effects on postidentification stages of naming are also expected from a dual coding perspective when the prime word and the name of the target picture share a verbal associative link. Consistent with this view, same-category word primes that were strongly associated with a target picture name yielded more priming than those with weaker associations (La Heij et al., 1990).

Phonological priming presumably affects name activation, response generation, or both, as shown by evidence that rhyming relations facilitate picture naming, which requires name activation, but do not facilitate picture categorization (natural vs. man-made objects), which may not require naming (Lupker & Williams, 1989). Phonological priming may result from spreading activation to phonologically similar words (Lupker & Williams, 1989) or from repetition of subprocesses required for response generation. Both of these suggestions, however, are inconsistent with the finding, noted earlier, that production of homonyms did not result in repetition priming of phonologically identical picture names (Wheeldon & Monsell, 1992). A possible reconciliation is that activation of one sense of a homonym produced inhibitory effects on the other sense, thereby offsetting phonological benefits.

Context also delays naming responses under certain conditions. For example, in the negative priming paradigm, naming is slowed when a picture that must be ignored on a previous trial

becomes the subsequent naming target (Tipper, 1985; Tipper & Driver, 1988). Similarly, naming may be delayed when context pictures render some of a target object's alternative names uninformative. If these alternatives become activated, they may then require inhibition to permit selection of a name that designates the target unambiguously (Johnson, 1994). These interference effects that are attributable to context pictures warrant further study.

Slowed picture naming is most often demonstrated in Stroop-like picture–word interference tasks, in which participants must name pictures with superimposed distractor words (Ehri, 1976; Glaser & Glaser, 1989; La Heij & Vermeij, 1987; Lupker & Katz, 1981; MacLeod, 1991; Roelofs, 1992; Rosinski, Golinkoff, & Kukish, 1975). The degree of interference depends on the nature of the distractor word and its relations with the pictured object. Words that share a semantic relation with the target picture cause more interference than unrelated words (Glaser & Düngelhoff, 1984; La Heij, 1988; Lupker, 1979; Rayner & Springer, 1986; Rosinski, 1977), which in turn cause more interference than pronounceable nonwords (Lupker, 1982). Words that share orthographic relations, phonological relations, or both with the name of the target picture, however, cause less interference than unrelated words (Lupker, 1982; Posnansky & Rayner, 1977; Rayner & Springer, 1986). Auditory presentation of distractor words yields a similar pattern of picture-naming interference. Semantically related words cause the most interference, unrelated words an intermediate amount, and phonologically related words the least (Schriefers et al., 1990).

Response competition appears to be the source of the basic picture–word interference effect (Lupker, 1979, 1982; Lupker & Katz, 1981). In general, resolution of competition between the name of the distractor word and that of the target picture delays responding. The degree of competition increases with factors that increase the overall activation of the distractor name, such as its word (vs. nonword) status (Lupker, 1982) and its inclusion in the response set (La Heij, 1988; La Heij & Vermeij, 1987; Neumann, 1986). Further experimentation is required, however, to determine precisely how and when the resolution of competition occurs during the interval between name activation and response articulation.

Additional interference may arise at the object identification stage of naming because perceptual processing mechanisms are engaged simultaneously by picture encoding and by referential activation of an image for the distractor word. This account could explain interference attributable to several factors, including visual similarity between the depicted object and an unrelated object named by the distractor word (Neumann, 1986), associative–categorical similarity between the target picture and distractor word (Lupker & Katz, 1981; Schriefers et al., 1990), and rated imageability of the distractor word (Lupker, 1979). In addition, simultaneous demand for visual encoding could explain interference caused by the mere presence of superimposed letters on the target picture (Lupker & Sanders, 1982).

Picture–word interference may also arise at or beyond the name activation stage (La Heij, 1988; La Heij et al., 1990). Moreover, the name activation stage, response generation stage, or both may be the loci of reductions in interference attributable to graphemic similarity, phonological similarity, or both between target and distractor names (Lupker, 1982; A. S. Meyer & Schriefers, 1991; Schriefers et al., 1990). Reduced interference occurs for phonologically related distractor words that share either beginning or ending elements with the target word, but the two effects show different time courses, suggesting that names are activated or prepared sequentially rather than in a whole-word fashion (A. S. Meyer & Schriefers, 1991).

A comprehensive account of context effects in picture naming needs to reconcile both priming and interference phenomena. Some dimensions of an account are already clear. First, both facilitation and interference arise at multiple stages of naming and reflect the influence of various similarity relations between context and target stimuli. For example, both priming and interference paradigms yield effects of visual similarity on object identification and of phonological similarity on postidentification stages of naming. Semantic similarity effects have not yet been clearly attributed to the associative relations central to dual coding theory or the categorical relations posited by certain amodal models. Second, the time interval between context and naming stimuli interacts with similarity to determine whether facilitation or interference occurs (Glaser & Düngelhoff, 1984; Glaser & Glaser, 1989; La Heij et al., 1990; Roelofs, 1992). Other influences may include spatial contiguity (Glaser & Glaser, 1989), participant expectations concerning stimulus relations (Huttenlocher & Kubicek, 1983), and task requirements (e.g., instructions and blocked vs. mixed presentation; Bajo, 1988). Another complexity is that, at times, facilitation and interference may cancel each other out (La Heij et al., 1990). There is also a need to reconcile context effects on correct responding and the production of naming errors (Martin, Weisberg, & Saffran, 1989; Vitkovitch & Humphreys, 1991; Vitkovitch, Humphreys, & Lloyd-Jones, 1993).

Summary: Naming Stages and Task Conditions

Theorists and researchers need to be clear about what they mean by semantic factors in naming, an issue at the heart of the controversy between proponents of dual coding and amodal models of naming. Tests of the alternatives particularly require differentiated predictions about the representation and functional roles of associative and categorical relations between and among objects and their names because current data do not compel the assumption of abstract categorical representations. A challenge for dual coding theorists is to develop reliable methods for obtaining associative data for objects (Paivio, 1991). Word association data are more readily available, but the effects of instructions, context, and other factors on associative processes in naming require careful study. Picture–word experiments that take advantage of the asymmetrical nature of word–word associations (e.g., R. Warren, 1974) may be revealing.

Phonological similarity effects on naming also require further investigation. Several recent proposals assume that word representations are organized according to similar phonological characteristics (Goldinger, Luce, & Pisoni, 1989; Wingfield, Goodglass, & Smith, 1990). If such an organization underlies phonological similarity effects in picture naming, the effects could be explained in terms of spreading activation over representational links among phonologically similar words, a match-

ing process whereby an activated word representation primes activity in a structurally similar name, or both. Either interpretation accords with dual coding assumptions (e.g., see a discussion of similarity effects in Paivio, 1986), and neither requires the assumption of amodal codes.

Effects of Participant Characteristics on Naming Stages

Participant characteristics also influence multiple stages of naming and, like many item attributes, such characteristics are also nonmanipulable and frequently intercorrelated. Participants who differ on a variable of interest (e.g., age and neurological status) often differ on other potentially relevant variables (e.g., vocabulary knowledge and health status). Research designs sensitive to these intercorrelations and converging evidence are thus essential in ruling out the influence of factors that may be correlated with the target characteristic.

Childhood Development

Children's naming of pictures becomes more proficient with development, as reflected in faster RTs and closer approximation to adult levels of accuracy (Berman et al., 1989; Clark & Johnson, 1994; Denckla & Rudel, 1974; German, 1986; Guilford & Nawojczyk, 1988). Changes in the nature and distribution of naming errors also accompany development (Fried-Oken, 1984; Rochford & Williams, 1962; Wiegel-Crump & Dennis, 1986; Wiig & Becker-Caplan, 1984), with omissions declining in favor of correct names and errors that are related semantically to the target. These changes presumably reflect the gradual accumulation and organization of both nonlinguistic and linguistic knowledge. A particularly challenging problem is to separate children's lack of word and object knowledge from naming difficulties per se. Another complication is that age is only a proxy for possible causal factors, such as biological maturation and experience. In this regard, developmental comparisons across such experimental manipulations as extended naming practice and novel object–name pairings could unconfound the role of experience from that of related factors.

Surprisingly few attempts have been made to determine which naming stages are affected by development. Logically, developmental changes could occur at any or all stages of naming and at similar or different rates across various stages. Additional evidence of stage-specific developmental changes would help constrain cognitive models by the need to account for both adult performance and developmental changes.

Some conflicting evidence concerning developmental changes in specific naming stages has been obtained from tasks requiring same–different judgments about the physical or name identity of various picture pairs. Differences in RTs between physical- and name-identity judgments are assumed to reflect the additional time required for name activation. Based on such judgments, Bisanz et al. (1979) and Hoving et al. (1974) reported that name activation time remains relatively constant from age 8 to early adulthood, whereas Kail (1986, 1991) noted substantial developmental improvements in name-activation speed over the same age range. The reliable finding that physical-identity judgments become faster with age (Bisanz et al., 1979; Hoving et al., 1974; Kail, 1986) suggests that the perceptual stage, the response stage, or both of the identity task are also affected by maturation or relevant experience.

Of course, generalization from identity judgments to naming is only valid if both tasks involve similar identification and name-activation stages. Physical-identity judgments may be based on early processing of visual characteristics, whereas naming may require more extensive processing to achieve object identification, thus questioning the equivalence of the initial processing stages in the two tasks (Biederman & Cooper, 1992; R. Ellis et al., 1989). Likewise, name activation may not be comparable when overt name responses are required and when they are not (name-identity judgments).

In picture–word interference tasks, the finding that overall interference declines with development (Ehri, 1976; Rosinski, 1977; Rosinski et al., 1975) suggests a possible stage-specific change localized at response generation (see *Context*). Developmental changes in the resolution of response competition in various cognitive tasks (Bjorklund & Harnishfeger, 1990; Clark, 1992; Dempster, 1992; Tipper, Bourque, Anderson, & Brehaut, 1989), including naming, may reflect the gradual maturation of inhibitory mechanisms. For example, inhibitory improvements may underlie developmental changes in the efficiency of superordinate naming relative to basic level naming (Clark & Johnson, 1994; Johnson & Clark, 1988) and in the selection of object names appropriate to a particular communicative context (Johnson, 1994).

Experiments designed to reveal interactions between age and task conditions or item attributes thought to affect particular naming stages may yield further relevant evidence. For example, interactions between age and experimentally varied stimulus attributes, if found, may provide clues about the nature and extent of possible developmental changes in object-identification processes. The attempt to delineate naming changes associated with development (and aging, below) would also benefit from longitudinal work to supplement existing cross-sectional studies. Some researchers have assessed naming skills in children longitudinally (W. F. Katz, Curtiss, & Tallal, 1992; Scarborough, 1989, 1990; Wolf, 1984, 1986; Wolf, Bally, & Morris, 1986; Wolf & Goodglass, 1986), but their studies were not designed to determine how specific stages of naming are affected by developmental factors.

Interestingly, the debate over amodal representations appears to have little presence in the developmental literature, despite its obvious relevance. Among the issues that have been ignored are at what age the conceptual representations emerge, whether links between object and word representations are possible before conceptual representations, and—if they are possible—what happens to these direct links following acquisition of conceptual representations. Specific predictions about these issues could provide important tests for amodal theories.

Aging

At the other end of the life span (60 years or older), aging may result in slower naming, less accurate naming, or both (Albert, Duffy, & Naeser, 1987; Albert, Heller, & Milberg, 1988; Butterfield & Butterfield, 1977; Mitchell, 1989; Obler & Albert, 1985; Thomas et al., 1977). Some researchers have argued that differences in health status, education, and other cohort effects

could explain many, perhaps all, of these findings (Goulet, Ska, & Kahn, 1994; LaBarge, Edwards, & Knesevich, 1986; Poon & Fozard, 1978). We think it is reasonable to exclude educational and experiential differences from definitions of aging but disagree with excluding health differences that reflect physiological changes integral to aging.

Slowed or inaccurate naming responses associated with aging could arise at any or all stages of naming. Thomas et al. (1977) suggested perceptual identification as a locus for aging-related increases in (a) perceptually based naming errors, (b) exposure durations required for picture identification, and (c) matching times for pictures. Unfortunately, these results do not necessarily implicate only perceptual processing. The error data could reflect inaccurate name activation, whereas the identification and matching results might indicate slow response execution. Aging-related decreases in inhibitory efficiency (e.g., Hasher, Stoltzfus, Zacks, & Rypma, 1991) may also affect naming, especially the resolution of response uncertainty and access to less readily available names (e.g., superordinates).

An adequate account of naming needs to accommodate both continuities and changes across the life span. One reported continuity is that the degree of repetition priming from renaming the same picture may be relatively constant across development (M. Carroll et al., 1985; Lorsbach & Morris, 1991) and aging (Mitchell, 1989), but this interpretation of the data is uncertain. Continuity appears evident when comparisons are based on the absolute amount of facilitation, whereas the same results suggest development change when relative measures of facilitation are used (e.g., facilitation relative to time for first naming). Finally, life span differences in naming need to be reconciled with individual differences, which are discussed next.

Ability

Individual differences in both verbal and nonverbal abilities should influence naming proficiency (Paivio, 1971, 1986). Some support for this assertion comes from studies of performance on standardized naming tests (M. F. Gardner, 1979, 1983; German, 1986; Kaplan, Goodglass, & Weintraub, 1983). Naming test scores load on both verbal and nonverbal memory factors (Sewell, Downey, & Sinnett, 1988) and correlate positively with individual differences in comprehension–vocabulary skill, $rs = .46–.80$, and IQ, $rs = .39–.83$ (Furlong & Teuber, 1984; M. F. Gardner, 1979, 1983; Goldstein, Allen, & Fleming, 1982; Johnson, Paivio, & Clark, 1989; Scarborough, 1989, 1990; Sewell et al., 1988). The relation between comprehension and naming skills is at least partly independent of age (Thomas et al., 1977).

Some experimental work links nonverbal abilities with naming proficiency. C. K. Thompson, Hall, and Sison (1986) demonstrated that imagery training improved the naming accuracy of several participants with aphasia. Imagery training also formed part of an intervention program that enhanced the picture-naming accuracy of children with language impairments (Wing, 1990), but because this program was multifaceted, it is not clear whether the imagery training was responsible for the naming gains.

Although these reports of relations between ability differences and naming are promising, we do not yet know which stages of naming are influenced by various abilities. The general nature of IQ and comprehension–vocabulary measures could make it difficult to identify specific relations with performance on particular stages. A more productive approach might be to search for relations between naming performance and abilities that have more specific theoretical connections to each stage. For example, object-identification proficiency might be related to certain imagery abilities, name-activation speed to other measures of referential processing skill (e.g., Bucci, 1984), and efficient response generation to articulatory speed (Ackerman, Dykman, & Gardner, 1990).

Bilingualism

Picture naming and other language tasks have been used to explore the functional independence or interdependence of nonlinguistic and linguistic representational systems in individuals who speak more than one language. The representational issues are too complex to address fully, but both amodal and dual coding models of bilingualism have been elaborated elsewhere (e.g., Kroll & Stewart, 1994; Paivio, 1986). The key difference, of course, concerns the need to posit amodal conceptual representations. Points of agreement are that the specifics of bilingual representation depend on whether two languages are acquired at the same or different times, in similar or distinct contexts, and to comparable or different levels of proficiency.

In general, individuals who speak more than one language name pictures more readily in their first or dominant language (L1) than in their second language (L2; Ehri & Ryan, 1980; Goggin et al., 1994; Kroll & Stewart, 1994; Potter, So, von Eckardt, & Feldman, 1984). Such differences presumably arise primarily at postidentification stages of naming, reflecting the greater strength and certainty (Goggin et al., 1994) of object–name connections in L1 relative to L2.

Object–name links may become operational early in L2 learning, as shown by evidence that naming pictures in L2 can be done as quickly as translating from L1 to L2. This suggests that picture naming does not occur indirectly by way of covert naming in L1 and translation to L2 (Potter et al., 1984). The interpretation is complicated, however, by the fact that picture naming is sometimes slower than translating (Snodgrass, 1993). Potter et al. went on to conclude that pictures were named, not by direct associations between languages but by way of an underlying common concept, the amodal representations at issue. However, nothing in their results required that assumption, inasmuch as the predicted effects would also follow from direct links between imagens and the L2 names. The conceptual representations were unnecessary.

Interference and facilitation effects in individuals who speak more than one language appear to arise primarily at postidentification stages of naming. For example, picture naming is primed by a prior production of a same-language name-word but not a different-language equivalent (Monsell et al., 1992), suggesting a locus in language-specific name representations rather than in object or conceptual representations common to both languages. In contrast, picture–word interference, thought to reflect response competition, is evoked by distractor words in either of an individual's two languages (Ehri & Ryan, 1980).

These individuals also experience interference in naming pictures in L1 and in translating words from L1 into L2 when picture or word stimuli are grouped into superordinate categories rather than randomized (Kroll & Stewart, 1994). Categorical interference does not arise in L2 to L1 word translation. Thus, the interference in naming and L1–L2 translation was attributed to repeated activation of related amodal concept–name links, with L2 to L1 translation, instead, occurring through direct word–word links. As discussed earlier (see *Context*), the dual coding view emphasizes the theoretical importance of isolating the relative contributions of visual, associative, and referential relations to such categorical effects. The interference observed by Kroll and Stewart, for example, could result solely from activation of competing superordinate names.

Neurological Impairment

Naming is particularly vulnerable to neurological insult. Focal left-hemisphere lesions often lead to the marked naming difficulties experienced by individuals with all subtypes of aphasia, especially anomic aphasia (Buckingham, 1981; Caplan, 1987; Caramazza & Berndt, 1978; Geschwind, 1967; Goodglass, 1980, 1993; Horner, 1986). Naming problems may also occur in individuals with right-hemisphere lesions (Myers, 1986) or diffuse brain damage, such as that associated with the dementias (for a review, see Nebes, 1989), progressive neurological diseases (Lethlean & Murdoch, 1994), closed head injuries (Tonkovich, 1988), or oxygen deprivation secondary to cardiac conditions (Tweedy & Schulman, 1982). Children with brain lesions may also exhibit naming problems (Aram, Ekelman, & Whitaker, 1987).

In principle, models of naming could be constrained by the patterns of naming breakdown that are observed in individuals with neurological impairments. However, such naming problems are difficult to isolate from other cognitive deficits arising from neurological damage or normal aging. Moreover, patterns of naming disruption vary greatly between and within individuals and diagnostic categories, raising questions about the usefulness and definition of such categories and the relative merits of group and single participant research methods (McNeil, 1988). Group comparisons may obscure theoretically important individual differences, but single case methods may limit the generalizability of findings. Finally, although it is widely assumed that patterns of naming disruption depend on the loci and extent of the underlying lesions (Geschwind, 1967; Goodglass, 1980), specific brain–behavior relations have proven difficult to identify (Goodglass, 1993).

It seems clear, however, that selective deficits in object-identification processes underlie naming difficulties in patients with agnosia, a relatively rare neurological impairment (A. W. Ellis & Young, 1988; Ratcliff & Newcombe, 1982). Recognition deficits in patients with agnosia may be specific to a particular type of stimuli—such as colors, faces, or objects—or to a specific modality of presentation (see *Modality*). Farah and McClelland (1991; see also Farah, 1994) presented a simulation model in which category-specific naming deficits arise as a result of damage to modality-specific object representations. Behrmann et al. (1994) described an individual with a specific, visual object-recognition deficit, in which other possible loci for the naming deficit appear to be carefully ruled out. Well-documented cases of agnosia lend credence to the idea that object identification is a relatively separable, initial stage in naming.

In contrast, multiple loci are implicated in the naming deficits of adults with aphasia, the neurological population that has been most studied. A hallmark of individuals with aphasia is slow, inaccurate naming of pictured objects (Newcombe et al., 1971; Rochford & Williams, 1965). Naming errors are often related semantically to the target name (Kohn & Goodglass, 1985; Rinnert & Whitaker, 1973; Silver & Halpern, 1992; Williams & Canter, 1982; Williams & Wright, 1985). However, as discussed earlier, these so-called semantic errors can have different origins, including misidentification of the object, activation of an incorrect name, or both. Factors that affect naming difficulty (e.g., uncertainty and word frequency) may pose particular problems for individuals with aphasia (Mills et al., 1979; Newcombe et al., 1965).

Traditionally, picture-naming difficulties in individuals with aphasia have been characterized as word-retrieval problems that occur subsequent to correct perceptual identification of the target item. Both nonverbal and verbal representations and associative structures are assumed to be grossly intact, but the target name is inaccessible. This characterization seems appropriate, at least in broad terms, for many individuals with aphasia (Gainotti, Silveri, Villa, & Miceli, 1986). Relatively intact, nonlinguistic processing is often demonstrated by the individual's ability to pantomime or describe the appropriate use of the pictured object or match the picture to its corresponding object. In addition, individuals with aphasia can often recognize a spoken name and match it to the correct object, suggesting that the correct name is represented and mentally connected to the object representation (at least in the verbal to nonverbal direction). Moreover, activation of the correct name can sometimes be primed by various gestural, categorical, associative, syntactic, or phonemic cues (Barton et al., 1969; Hanlon, Brown, & Gerstman, 1990; Huntley, Pindzola, & Weidner, 1986; Li & Williams, 1990; Rochford & Williams, 1962, 1963; Wingfield et al., 1990). Even when unable to produce the correct name, some individuals with aphasia, such as those in the "tip of the tongue" state (R. Brown & McNeill, 1966), demonstrated above-chance knowledge of general word features, such as its initial sound, length, and number of syllables (Barton, 1971; Gainotti et al., 1986).

Caution is warranted, however, because this traditional view of individuals with aphasic naming deficits is often based on performance in comprehension tasks that may be less sensitive than picture naming to subtle nonverbal, referential, or verbal deficits. For instance, partial or incomplete object knowledge may suffice to choose a named picture from a limited set of relatively distinct alternatives. Word knowledge demonstrated in definitions or gestures may be partial or ambiguous. For example, the definition "something for your foot" or a gesture interpreted as meaning *shoe* are equally appropriate for *boot* or *sock*. Moreover, some individuals with aphasia show naming and comprehension errors on the same picture–word items (Gainotti et al., 1986), suggesting a possible common underlying cause. These observations and others suggest that naming impairments in individuals with aphasia may not be limited to word retrieval.

Object identification may be affected by the subtle deficits that individuals with aphasia show on tasks that presumably reflect the integrity and organization of nonlinguistic representations, for example, drawing objects previously seen in pictures (Gainotti, Silveri, Villa, & Caltagirone, 1983), judging perceptual similarity between objects (Caramazza, Berndt, & Brownell, 1982), sorting exemplars from the same category into related clusters (Kelter, Cohen, Engel, List, & Strohner, 1977), discriminating real objects from nonobjects (Riddoch & Humphreys, 1987), verifying category and property attributes (Koemeda-Lutz, Cohen, & Meier, 1987), recognizing an object based on its pantomimed use (Huff, Mack, Mahlmann, & Greenberg, 1988), abstracting a prototype from repeated exposure to category exemplars (Wayland & Taplin, 1982), and performing visual perceptual tests (Wayland & Taplin, 1982). These nonverbal deficits are sometimes correlated with aspects of naming performance (Kelter et al., 1977; Wayland & Taplin, 1982). Nonetheless, it is not yet clear whether subtle deficits in nonlinguistic representations and organization are causally related to aphasic naming impairments and, if so, by what mechanisms these nonverbal differences affect processing at the object identification stage, subsequent stages of naming, or both.

Theoretically, referential links between nonverbal and verbal representations also may be damaged or used inefficiently in individuals with aphasia, thereby affecting name activation. Possible referential influences on naming are difficult, however, to isolate empirically from those of nonverbal, verbal, or general cognitive factors.

The integrity or functional use of verbal representations and their associative structures also may be compromised in many individuals with aphasia, perhaps influencing postidentification stages of naming. Weak, inaccurate, or poorly activated verbal representations in individuals with aphasia may also account for comprehension problems on lexical items and larger linguistic units (Gainotti et al., 1986; McNeil, 1988), limited knowledge of the phonological features of unretrieved picture names (Gainotti et al., 1986), and the increased length of word onset segments required to identify spoken words, relative to that needed by individuals without aphasia (Wingfield et al., 1990). Breakdowns in the interunit organization of verbal representations in individuals with aphasia may explain unusual patterns of similarity judgments for semantically related words (Zurif, Caramazza, Myerson, & Galvin, 1974), but such results cannot be attributed unambiguously to verbal representational or associative deficits yet.

Aphasic naming difficulties may also arise at the response generation stage of naming (Miceli, Giustolisi, & Caramazza, 1991). For example, praxic disorders (problems in initiating voluntary movements) regularly co-occur with Broca's aphasia and may underlie the hesitant, groping articulatory errors shown by individuals with these disorders. Response generation also may be the locus of the sound substitution and transposition errors made by individuals with conduction aphasia. These individuals often recognize their errors (suggesting that the target name is known) but remain unable to correct them, even when given an auditory model to imitate (Goodglass, 1980).

Most naming deficits associated with aphasia likely reflect complex interactions among nonverbal, verbal, and referential representations and processes that are damaged or preserved to varying degrees in each individual. None, however, appear to necessitate an amodal representation interposed between object and word representations. Although abstract semantic codes are often mentioned in the neuropsychological literature (e.g., Farah, 1994), naming deficits can be adequately conceptualized in terms of modality-specific object and word representations and their interconnections (Clark, 1994).

Developmental Disorders

Naming difficulties are also associated with language, learning, and reading disorders during childhood. Children with language impairments name pictures more slowly and less accurately than their control peers (Fried-Oken, 1984; Kail & Leonard, 1986; W. F. Katz et al., 1992; Leonard et al., 1983; Nippold, 1992; Wiig & Becker-Caplan, 1984; Wiig, Semel, & Nystrom, 1982). Because children with language impairments comprise a large proportion of children diagnosed as learning disabled (Wiig & Semel, 1984), dyslexic (Mattis, French, & Rapin, 1975), or both, many children with learning disabilities such as dyslexia show similar naming deficits (Badian, 1993; Denckla & Rudel, 1976a, 1976b; Denckla, Rudel, & Broman, 1981; German, 1979, 1982, 1984, 1986; L. A. Murphy, Pollatsek, & Well, 1988). Children with developmental impairments may be especially disadvantaged by item attributes that affect naming difficulty, such as word frequency and word length (R. B. Katz, 1986; Rudel et al., 1981), or by difficult naming conditions, involving picture–word interference (Lovdahl, Brown, McIntyre, & North, 1986) or requiring repeated, rapid name retrieval (Bowers & Swanson, 1991; Wolf, 1986; Wolff, Michel, & Ovrut, 1990a). Of potential educational significance is the finding that early deficits in naming predict eventual difficulties in learning to read (Jansky & DeHirsch, 1972; Scarborough, 1989; Wolf, 1982, 1984, 1986; Wolf et al., 1986; Wolf & Goodglass, 1986). The relations between naming and reading are at least partly independent of IQ, comprehension vocabulary knowledge, or both (Bowers, Steffy, & Tate, 1988; Felton & Wood, 1989; Scarborough, 1989; Snowling, van Wagtendonk, & Stafford, 1988; Wolf & Goodglass, 1986; Wolf & Obregon, 1992) and may reflect a common requirement for proficiency in memory retrieval across both tasks (Bowers et al., 1988; Wolf, 1982). Associations among naming proficiency and various reading measures may change as children develop (for a review, see Wolf, 1991), but naming deficits persist in adults with dyslexia (Pennington, van Orden, Smith, Green, & Haith, 1990; Wolff et al., 1990a).

Most naming research on children with developmental disorders has been designed to document an overall deficit rather than to reveal the source(s) of that deficit in terms of naming stages. Some of these children may, indeed, have an underlying pervasive deficit (e.g., slow activation processes or poor inhibitory efficiency) that could affect multiple naming stages. Most often, however, the naming problems associated with developmental disorders, like those characteristic of aphasia, are assumed to reflect name-retrieval difficulties. Nonlinguistic representations and processes are presumed to be intact because children with developmental disabilities are frequently (but not always; Siegel, 1989) defined as having nonverbal IQs in the

normal range. Names are assumed to be temporarily inaccessible when they cannot be produced in response to a picture. That these names are nonetheless available is shown by their production in other situations, their facilitation by various types of cuing (Rubin, Bernstein, & Katz, 1989), and their comprehension. Comprehension and nonlinguistic competence, however, are often assumed rather than assessed and, even when tested, may be subject to the problems of sensitivity discussed earlier.

L. A. Murphy et al. (1988) provided one of the few direct tests of the assumption that nonlinguistic processing is intact. Children with dyslexia did not differ from IQ-matched controls in simple motor RTs and speed in verifying pictures as exemplars of common categories but were inferior to controls in naming, reading, and other language tasks. Similarly, N. Ellis (1981) found that children with dyslexia did not differ from controls in choice RTs or speed to compare stimuli on visual characteristics but were slower to compare stimuli on name information. Such results indirectly support the traditional view that developmental impairments primarily affect the name activation stage, perhaps reflecting weak or incomplete representations of the auditory–motor (phonological) aspects of words (Pennington et al., 1990; Rubin et al., 1989).

Subtle deficits in perceptual processing, motor responding, or both suggest that other stages of picture naming may be affected in at least some children with developmental disorders. Children with language impairments took longer than their age-matched controls to match physically identical pictures—a task that presumably requires perceptual identification and motor responding (different from that required for naming) but does not require name activation (Kail & Leonard, 1986). Children with dyslexia made more naming errors than their control peers, particularly at short-picture exposure durations and fast presentation rates, thereby implicating visual processing differences (Wolff et al., 1990a). Children with dyslexia also differed from control readers on certain low level visual tasks requiring spatial and temporal frequency analysis (Lovegrove, Martin, & Slaghuis, 1986), although it is not yet clear whether and how such deficits might affect object identification in naming tasks.

Some children with developmental impairments also exhibit problems in motor control of the precise, rapidly changing movements required for complex articulatory and manual tasks (W. F. Katz et al., 1992; Wolff, Cohen, & Drake, 1984; Wolff, Michel, & Ovrut, 1990b; Wolff, Michel, Ovrut, & Drake, 1990). These motor difficulties sometimes correlate with the severity of naming or reading impairments (W. F. Katz et al., 1992; Wolff et al., 1984, 1990b), indirectly implicating response generation as a locus of developmental naming difficulties. Deficient word representations could also hinder response generation.

As in the case of neurological impairments, it is clear that various developmental impairments are associated with naming deficits. What is less clear is how and where these deficits originate with respect to the various cognitive stages of naming. One way to make inroads might be to design interventions that target particular naming stages. The resulting successes or failures could then provide further clues concerning the loci of developmental impairments (or, for that matter, neurological impairments, developmental differences, or ability differences). Most naming interventions tested to date (Casby, 1992; Hyde-Wright, Gorrie, Haynes, & Shipman, 1993; McGregor & Leonard, 1989; Rubin, Rotella, Schwartz, & Bernstein, 1991; Wing, 1990) have not been linked clearly to a particular stage of naming (but see McGregor, 1994; and C. K. Thompson et al., 1986, for possible exceptions). To our knowledge, none of the conceptualizations of developmental naming disorders depend on amodal, semantic codes, suggesting that this assumption is irrelevant or at least unappreciated to date.

Summary: Naming Stages and Participant Characteristics

Increased application of theoretically relevant methods could improve the potential value of research on participant characteristics to constrain cognitive models of naming. Particularly informative might be experiments seeking interactions between participant characteristics and item attributes or task conditions that affect particular naming stages (e.g., Clark & Johnson, 1994) and studies whose researchers assess the effects of various intercorrelated participant characteristics on naming. We also urge theorists and researchers alike to question whether empirical data on the effects of various participant characteristics on naming can be explained without assuming abstract representations.

Conclusions

Naming is a complex process central to human cognition. Naming encompasses at least the three broad stages of object identification, name activation, and response generation. In this review, we considered these stages in turn and, where possible, attributed known effects of item attributes, task conditions, and participant characteristics to particular stages. Table 1, which summarizes this information, identifies findings in need of confirmation and suggests novel hypotheses concerning variables relevant to particular naming stages. Moreover, the studies cited in this review could be used to calculate possible effect sizes and to guide other methodological decisions concerning future research. Such paradigms as experimental manipulations of item attributes and tests for interactions among nonmanipulable and manipulable variables may be particularly helpful in bolstering conclusions currently based on quasi-experimental or observational evidence. Nonexperimental research on item attributes and participant characteristics would also benefit from more robust multivariate approaches sensitive to the undoubtedly complex intercorrelations among these variables.

At a theoretical level, we argued that the modality-specific representations, referential connections, and associative processes posited by dual coding theory are sufficient to explain most of the known naming findings. In particular, there is no clear support for the widely held belief that picture naming requires mediation by an amodal conceptual representation. A dual coding model not only handles the naming results but also accounts for a wide range of findings in cognitive domains outside of picture naming (Paivio, 1983, 1986, 1991). We, however, emphasized that all cognitive models of naming, including

Table 1
Effects of Independent Variables on Object Identification (Ident), Name Activation (Name), and Response Generation (Resp) Stages of Picture Naming

Variable	Overall effect	Effect		
		Ident stage	Name stage	Resp stage
Item attributes				
Stimulus quality	++	+		
Stimulus size	+	+		
Stimulus realism	?	?	?	
Stimulus complexity	+			
Stimulus familiarity	+			
Canonical perspective	++	+		
Modality	?			
Uncertainty	++		+[a]	+[a]
Stimulus comparisons	++		+[a]	+[a]
Generality	++	+	+[a]	+[a]
Word frequency	++		+	
Age at acquisition	++			
Word length	+			+
Task conditions				
Practice	++	++	+	
Context	++	++	+	+
Participant characteristics				
Development	++	+	?	+
Aging	+			
Ability				
Nonverbal	+			
Verbal	++			
Bilingualism	++		+	
Neurological impairment	++	+	+	+
Development disorders	++	+	+	+

Note. Symbols indicate experimental evidence in support of an overall effect on picture naming, a locus at a particular stage, or both. ++ = definite (more than five studies show consistent effect); + = probable (two to five studies show consistent effect); ? = inconsistent (existing studies show conflicting effects).
[a] Evidence for postidentification locus but not for specific stage.

the dual coding model, require further elaboration to permit specific tests of the alternatives in picture naming tasks.

Other key assumptions of naming models also need to be challenged because many have far less experimental support than one might assume from a selective reading of the literature. For example, excitatory processes, such as spreading activation, may be insufficient to explain naming performance. Findings in many areas (uncertainty, name generality, picture–name interference, development, aging, developmental disorders, and neurological impairments) suggest that inhibitory processes may control the spread of activation and permit selection of a specific object or name representation from a set of activated candidates (Berg & Schade, 1992; Clark & Johnson, 1994; Humphreys et al., 1988; Johnson, 1994; La Heij et al., 1990). Further advances in understanding naming may result from the testing of proposals that specify how and when such inhibitory processes may be invoked. Understanding the operation of these mechanisms is necessary to draw definitive conclusions about the need for abstract representations because processing and representational issues are intimately linked.

Also in need of attention are questions about the temporal organization of the hypothesized naming stages and the transfer of information between them. It is unknown, for example, whether stages occur successively in a strict serial order or concurrently in a simultaneous or overlapping manner. Even if stages unfold serially, processing could be parallel within stages (e.g., simultaneous activation of multiple object representations during identification). In addition, it is not known whether transfer of information between stages is continuous or occurs in a discrete, all-or-none step (i.e., stages have thresholds for information transfer). Continuous transfer could be uni- or bidirectional through feedback or cyclical connections (Dell & O'Seaghdha, 1991). Recent tests of serial-discrete and parallel-continuous models of picture naming (Humphreys et al., 1988; Levelt et al., 1991b; Martin et al., 1989) have yielded controversial results (Dell & O'Seaghdha, 1991; Harley, 1993; Levelt et al., 1991a; Vitkovitch et al., 1993). Replication of these studies and research using other methods to assess the temporal organization of cognitive processes (Luce, 1986; D. E. Meyer, Irwin, Osman, & Kounios, 1988; J. Miller, 1982; Posner, 1978; Townsend & Ashby, 1983; Yantis, Meyer, & Smith, 1991) could determine how best to conceptualize the organization of naming stages.

In closing, we note that picture-naming research will ultimately need to be integrated with substantial literatures on related topics, such as object recognition, reading, language comprehension, and discourse formulation. In reciprocal fashion, these areas will benefit from the rich and varied research on picture naming summarized and advocated in this article and from further elaboration of theoretical models of picture naming.

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