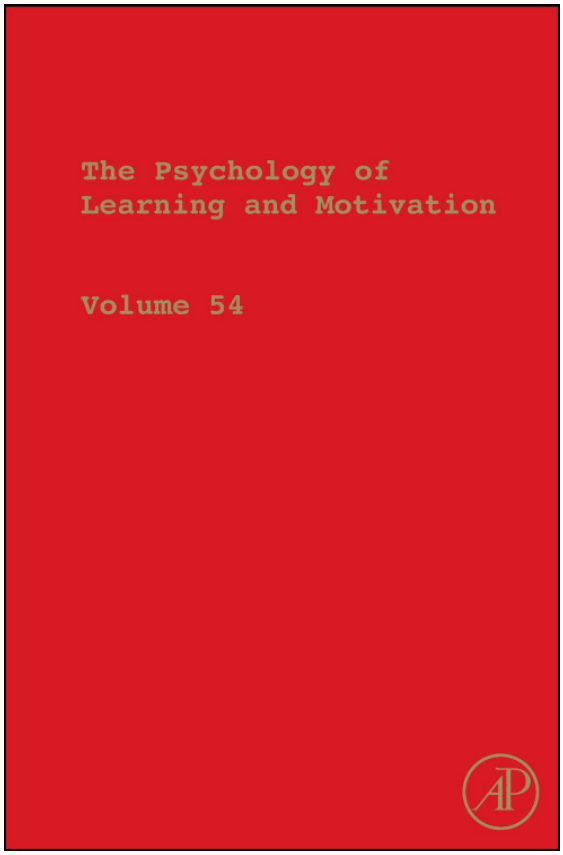

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CHAPTER EIGHT

Thematic Thinking: The Apprehension and Consequences of Thematic Relations

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Abstract

A thematic relation is a temporal, spatial, causal, or functional relation between things that perform complementary roles in the same scenario or event. For example, cows and milk are related by a production theme, and sails and anchors are related via a boating theme. Thematic relations are distinct from mere associations, scripts, and *ad hoc* categories. They also contrast and complement taxonomic (categorical) relations such as "fruits" and "furniture." Thematic relations and taxonomic relations arise from distinct processes, as evidenced by numerous neuropsychological and behavioral dissociations. Thematic relations may be apprehended uncontrollably and rapidly according to how frequently and recently they have been encountered. They exert profound effects on many core cognitive processes, including similarity, categorization, memory, language, inference, and analogy, and they exhibit robust processing differences across individuals and cultures. In sum, without such thematic thinking, models of cognition will remain categorically limited.

1. Introduction

Thematic relations group objects, concepts, or people together by virtue of their participation in the same scenario or event. This contrasts with taxonomic (or categorical) relations, which group things by common properties. Although taxonomic relations have received considerably more attention within psychology, thematic relations are also essential to cognition. They guide our assessment of similarity, organize our conceptual knowledge, and constrain our comprehension of language, among other cognitive functions. To understand how thematic relations play such an important role in cognition, it is useful to consider the different types of information that taxonomic and thematic relations convey.

Taxonomic relations underlie traditional feature-based categories. They allow us to simplify the rich perceptual world by treating nonidentical things as if they are the same, and they support inferential generalizations from one thing to another nonidentical thing. Knowing that avocado and aubergine are both foods, for example, can guide expectations and behaviors: classifying aubergine as a food tells us that it is edible, even if we have never encountered that particular food before. Taxonomic relations thus help us to interact appropriately with classes of objects, concepts, and even people. However, taxonomic relations do not help us generate expectations about events or scenarios. For example, how do we know what to expect when dining in a restaurant? Answering this question requires thematic relations. In the case of a restaurant, thematically related items might include food, menus, waiters, and wine. These items share few features, but they are nonetheless linked by their participation in a common event. Importantly,

thematic relations can help guide behavior with respect to events: if someone hands you a menu in a restaurant, you can reasonably expect a waiter to take your order. This inference is based on a thematic, rather than taxonomic, relation. Knowing that a menu is taxonomically related to a book (both contain pages with text) is not a useful basis for generating expectations within this event. So, thematic relations serve an essential organizing function in cognition. They convey knowledge about events and scenarios, which complement one's knowledge about features and taxonomic relations.

The goal of this chapter is to integrate and summarize the literature on thematic relations. We begin by defining thematic relations and by distinguishing them from several other theoretical constructs such as associative relations, scripts, and *ad hoc* categories (Section 2). Next, we elaborate on the dissociation between thematic and taxonomic relations, arguing that they are distinct constructs that arise from different processes (Section 3). We then consider the processing of thematic relations, with particular emphasis on properties such as controllability, speed, frequency, and recency (Section 4). We subsequently identify the importance of thematic relations for a number of basic cognitive processes, focusing specifically on similarity, memory, categorization, language, and analogy (Section 5). Finally, we discuss individual and cultural differences in the prevalence of thematic thinking. The purpose of this integrative review is to highlight the unique and significant contribution of thematic relations to cognition at large.

2. Definition and Differentiation

Before detailing their apprehension and consequences for other cognitive processes, it is necessary to provide a more precise definition of thematic relations and to differentiate them from other theoretical constructs. Throughout the remainder of this chapter, we denote concepts in small caps and thematic relations in underlined text.

2.1. Definition of Thematic Relations

Generally speaking, a *thematic relation* is any temporal, spatial, causal, or functional relation between things. More specifically, things are *thematically related* if they perform complementary roles in the same scenario or event (Golonka & Estes, 2009; Lin & Murphy, 2001; Wisniewski & Bassok, 1999). For example, COW and MILK are related by a production theme, BOOKS and SPECTACLES are related by a reading theme, and SAILS and ANCHORS are related via a boating theme. In each of these cases, the two things perform complementary thematic roles. COWS are producers and

their MILK is the product. A BOOK is the object and SPECTACLES are an instrument of reading. SAILS and ANCHORS are both parts of a boat, but they perform different functions. Note that those thematic roles need not *complete* the theme; they need only *complement* one another in the sense of fulfilling distinct roles. For instance, SAIL and ANCHOR complement one another, but they clearly do not complete the boating theme. Among the most typical thematic relations are spatial (e.g., JUNGLE and BIRD), temporal (e.g., SUMMER and HOLIDAY), causal (e.g., WIND and EROSION), functional (e.g., FORK and KNIFE), possessive (e.g., POLICE and BADGE), and productive relations (e.g., COW and MILK).

Critically, thematic relations are "external" in that they occur between multiple objects, concepts, people, or events. This contrasts with "internal" features and relations among features, which occur within a single entity. To illustrate, DOGS are furry and have a tail connected to the hindquarters. Both of these are internal properties because they predicate the concept in itself; they entail no other object, concept, person, or event. But the fact that DOGS chase SQUIRRELS is an external property of DOGS because it could not occur without its complementary concept, SQUIRRELS. Thus, the key properties of a thematic relation are

(1) *Externality*—thematic relations occur between two or more things.
(2) *Complementarity*—those things must fulfill different roles in the given theme.

As we show in the following sections, these two properties are crucial for differentiating thematic relations from mere association, scripts, *ad hoc* categories, and taxonomic relations (see Figure 1).

Thematic relations can arise from either affordance or convention. Regarding affordance, some things have features that allow them to interact with other things in specific ways (Maguire, Maguire, & Cater, 2010). For instance, because HAMMERS are graspable and have a large, heavy, and flat head, they afford hitting. And because NAILS have a small, flat head, they afford being hit. The thematic relation between HAMMER and NAIL is therefore based on their affordances. Not all thematic relations, however, are affordance based. For instance, a WINE GLASS and a DINNER PLATE are thematically related by convention, in that they frequently co-occur in a meal theme. But their features do not afford specific interactions between GLASSES and PLATES to the same extent that HAMMERS and NAILS interact. GLASSES and PLATES clearly perform complementary roles in the meal theme, but they are less directly interactive than HAMMERS and NAILS. Moreover, thematic relations can arise between objects that have no conventional relationship but do have complementary affordances. One can use a ROCK to hit a NAIL because ROCKS, like HAMMERS, afford hitting (although a ROCK is less well suited than a HAMMER). Thematic relations usually entail some combination of affordance and convention.

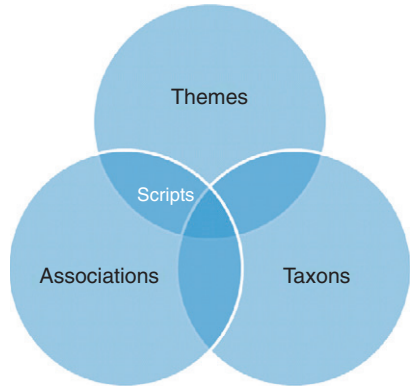

Figure 1 A typology of semantic relations, illustrating the differentiation of thematic relations from associative, taxonomic, and script relations.

2.2. Differentiation from Mere Association

Concepts are *associated* if one evokes thoughts of the other. Association has been invoked to explain a great many behavioral phenomena (e.g., Grosset, Barrouillet, & Markovits, 2005; Martin & Cheng, 2006; Snyder & Munakata, 2008), but as a theoretical construct it is poorly defined (e.g., Bradley & Glenberg, 1983; Hutchison, 2003; McRae & Boisvert, 1998; Moss, Ostrin, Tyler, & Marslen-Wilson, 1995; Spence & Owens, 1990; Thompson-Schill, Kurtz, & Gabriele, 1998). In practice, most researchers have operationally defined association in terms of free association probabilities, where the likelihood of producing a given target word in response to a specific cue word is their *association strength*. For example, given the cue word "birthday" in the free association task, the probability of a "cake" response is 0.192 (Nelson, McEvoy, & Schreiber, 1998). There are numerous ways in which concepts may be associated. Associates can be synonyms (e.g., BIG → TALL), antonyms (e.g., BLACK → WHITE), category comembers (e.g., HORSE → COW), or conventional phrases (e.g., FOOT → BALL), among others. Associated concepts therefore always have some other, more specific relation between them. For many associated concepts, that more specific relation is thematic. For instance, "milk" is strongly associated with "cow" (free association probability = 0.388), and this association is explained by the thematic relation that COWS produce MILK.

However, many associated concepts are not thematically related. "Lion" is strongly associated with "tiger" (0.362), yet they are not thematically related. Their associative relationship is based on taxonomic categorization (i.e., both are large cats) and lexical co-occurrence (e.g., "Lions, tigers, and bears. . ."), not upon participation in the same scenario or event. LIONS live on savannahs, TIGERS live in jungles, and they do not interact. So LIONS and

TIGERS are neither externally related nor complementary. Moreover, many thematically related concepts are unassociated (Estes & Jones, 2009; Simmons & Estes, 2008). "Milk" and "cat" are not associated (free association probability < 0.01) but are thematically related: like all mammals, CATS also produce MILK and they are renowned for consuming it. Similarly, APPLE and GRAVITY are unassociated, but they are thematically related in the context of Newton's discovery of gravity. Clearly then, thematic relations are not merely associations between things. This partially overlapping relationship is illustrated in Figure 1.

The differentiation from association is important because it indicates that thematic relations may occur not only between concepts that *do* interact and therefore are associated (e.g., HAMMER and NAIL) but also between concepts that simply *could* interact and therefore are unassociated (e.g., ROCK and NAIL). Indeed, several studies have shown that thematic relations exert similar effects regardless of whether the related concepts are associated or unassociated (e.g., Estes & Jones, 2009; Hare, Jones, Thomson, Kelly, & McRae, 2009; Jones, 2010; Nation & Snowling, 1999; Scheuner, Bonthoux, Cannard, & Blaye, 2004; Simmons & Estes, 2008). How can unassociated things come to be thematically related? Thematic relations can emerge between unassociated things if their features afford specific interactions (see Section 2.1).

2.3. Differentiation from Scripts

A *script* is a generalized sequence of actions and instruments associated with the execution of some common event (Bower, Black, & Turner, 1979; Schank & Abelson, 1977). For example, a bowling script includes such instruments as a BOWLING ALLEY, BOWLING BALLS, and PINS, and such actions as selecting a BALL and attempting to upend the PINS by bowling the BALL down the ALLEY. The various objects, concepts, people, and actions involved in the execution of a script are externally related by the event itself, and they perform complementary roles in the execution of the script. Thus, scripts are a particular type of thematic relation (see Figure 1). However, not all thematic relations are embedded in scripts. Because scripts involve common events, their actions (e.g., BOWLING) and instruments (e.g., BALL) tend to be associated. But as explained in Section 2.2, many thematically related things are not associated. Even though a DOG and a TATTOO are unassociated, people can readily infer a thematic relation between them. The concepts involved in a script *do* co-occur, whereas the concepts involved in a thematic relation merely *could* co-occur. So scripts are a subset of thematic relations, but thematic relations additionally include unassociated things. This generality beyond association lends greater explanatory power to thematic relations.

2.4. Differentiation from *Ad Hoc* Categories

An *ad hoc category* is one that is created spontaneously to achieve some goal (Barsalou, 1983). Examples include THINGS TO REMOVE FROM A BURNING HOUSE and THINGS NOT TO EAT ON A DIET. Because the goal around which an *ad hoc* category is based may resemble a theme (e.g., a burning house theme or a diet theme), *ad hoc* categories are easily confused with thematic relations. However, such *ad hoc* categories differ importantly from themes (Lin & Murphy, 2001). Members of an *ad hoc* category go together as a result of some internal, goal-based property that they all possess (see Barsalou, 1983, p. 225). All members of THINGS TO REMOVE FROM A BURNING HOUSE have some property (i.e., value) that identifies them for salvaging. It could be monetary value (e.g., JEWELRY), sentimental value (e.g., PHOTOS), or some other value (e.g., PETS). Moreover, the members of such *ad hoc* categories are noncomplementary. JEWELRY, PHOTOS, and PETS do not functionally complement one another like BOATS, SAILS, and ANCHORS do. Rather, they all serve the same goal of salvaging valuables from a burning house. Without the goal, those things no longer cohere or relate to one another in any obvious way. Themes, in contrast, are networks of external relations in which the constituents fulfill complementary roles. A SAIL and an ANCHOR cohere not because they share some property; in fact, the sail is large and light, whereas the anchor is small and heavy. Rather, they cohere because they perform complementary functions in the sailing theme. So whereas an *ad hoc* category is based around some shared internal property that serves the same goal among all its members, a theme is based around some external relation in which each constituent performs different roles. That is, *ad hoc* categories are internal and noncomplementary, and hence they differ fundamentally from thematic relations.

2.5. Differentiation from Taxonomic Relations

Taxonomic relations entail membership in a common category on the basis of shared features. For example, WHALES and HORSES share important features (e.g., being warm-blooded and bearing live offspring) and hence belong to the same taxonomic category of "mammals." PIZZA and CHIPS, due to their shared property of being edible, are both members of the "food" category. Concepts belong in a taxonomic category, and hence are taxonomically related to all other category members, by virtue of shared properties. In order for something to be FOOD, it must be edible. And for something to be a MAMMAL, it must be warm-blooded, produce milk, and bear live young. Moreover, taxonomically related concepts are typically not complementary. WHALES and HORSES do not normally complement one another in any theme. Thus, taxonomic relations are based on the properties of the objects themselves, and taxonomic categories cohere around shared

properties (Hampton, 2006; Markman & Wisniewski, 1997; Rosch, 1975). As a consequence, taxonomically related concepts tend to resemble one another.

In contrast, thematically related concepts tend *not* to resemble one another, because thematic categories cohere around complementary roles rather than shared properties. The contrasting thematic roles of OWLS and MICE as predator and prey, respectively, require different features. The OWL must be larger than the MOUSE in order to capture it, and the MOUSE must be quicker than the OWL in order to evade it. To propel a boat, a SAIL must be large and relatively light. But to moor the boat, its ANCHOR must be relatively small and heavy. This is not to say that all thematically related concepts are taxonomically unrelated (see Figure 1). After all, OWLS and MICE are both animals, and MILK and COFFEE are both consumable liquids. HORSES and COWS, while taxonomically related by the "mammal" category, are also thematically related in that HORSES are often used to corral CATTLE. So taxonomic and thematic relations are theoretically orthogonal. Generally speaking though, in order for two things to perform different roles in the same theme, they typically differ in important respects. Consequently, thematically related concepts tend to be featurally dissimilar (Estes, 2003a; Estes & Jones, 2009; Golonka & Estes, 2009; Lin & Murphy, 2001; Wilkenfeld & Ward, 2001; Wisniewski, 1996; Wisniewski & Bassok, 1999; Wisniewski & Love, 1998).

3. Dissociating Thematic Relations from Taxonomic (Categorical) Relations

The distinction between thematic relations and taxonomic relations is more than theoretical. Rather, thematic thinking and taxonomic thinking appear to arise from distinct processes. Evidence from neurological impairments and neuroimaging both indicate that thematic processing and taxonomic processing have important differences in neural topography and cortical networks. Purely behavioral studies with neurologically intact participants also suggest that thematic processing and taxonomic processing may be differentially affected by and may have differential effects on other behaviors.

Before reviewing these numerous dissociations, a methodological and terminological consideration is necessary. By far, the single most common method used to measure thematic thinking is the *matching-to-sample* task (see Figure 2). In this task, a base stimulus is presented with two or more option stimuli, and participants are instructed to choose the option that matches the base on some given criterion. For instance, a typical trial might have DOG as the base, CAT as a taxonomically related option, and BONE as a thematically related option, with participants instructed to choose the option that "goes

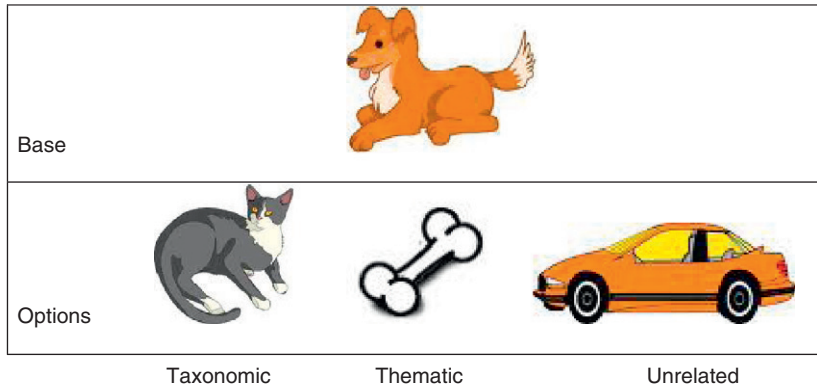

Figure 2 Example illustrating the matching-to-sample (a.k.a. matching) task, in which participants are instructed to select the option that matches the base on a given criterion (e.g., "which option goes with the base?"). A typical trial includes only two options, where a *taxonomic trial* contrasts taxonomic and unrelated options, a *thematic trial* contrasts thematic and unrelated options, and a *conflict trial* contrasts taxonomic and thematic options.

with" the base. This paradigm has several parameters, such as the mode of presentation (pictures or words), the number of options (two or more), the relation between the options and the base (e.g., taxonomic, thematic, or unrelated), and the choice criterion (e.g., "goes with," "is the same kind of thing"). In this paradigm, reliably choosing a thematic option over an unrelated option indicates apprehension of thematic relations, whereas reliably choosing a thematic option over a taxonomic option indicates a preference or processing advantage for thematic thinking (and vice versa for taxonomic choices). Despite some valid criticisms (see Section 5.2), this matching-to-sample task has been ubiquitously employed, and hence we refer to it often throughout the remainder of this chapter. For brevity, we refer to it as the "matching task."

3.1. Neuropsychological Dissociations

Neuropsychological dissociations between taxonomic processing and thematic processing have been observed. Davidoff and Roberson (2004) reported a case study of LEW, who had Wernicke's aphasia. In a matching task (see Figure 2), LEW was presented pictures of three objects and his task was to indicate which two best "go together." On different trials, LEW was instructed to respond on the basis of color, size, or function. For example, given a HAMMER, a NAIL, and a SCREW, the correct response on a size trial would be NAIL and SCREW, whereas the correct response on a function trial would be NAIL and HAMMER. LEW performed poorly on color (24%

accuracy) and size trials (52%), indicating impaired judgment of basic object features. However, he performed as well as control participants on functionally related, thematic trials (81%). Thus, despite impaired featural categorization, LEW's thematic categorization was spared.

Neuroimaging studies reveal that taxonomic and thematic processing also activate distinct cortical networks in normal participants. Sachs and colleagues have conducted a number of studies contrasting taxonomic from thematic processing. Sachs, Weis, Krings, Huber, and Kircher (2008) used a matching task in which participants selected which of two options best went with a target (e.g., CAR). Choosing a taxonomic match (e.g., BUS) over a thematic match (e.g., GARAGE) was associated with increased activation of the left thalamus, right middle frontal gyrus, and left precuneus. In a lexical decision task, Sachs, Weis, Zellagui, et al. (2008) found greater activation of the right precuneus from taxonomic prime-target pairs (e.g., CAR → BUS) than from thematic pairs (e.g., CAR → GARAGE). The increased activation of the precuneus across both studies could be due to the greater reliance of taxonomic processing upon perceptual information (Sachs, Weis, Krings, et al., 2008), or upon less salient meanings of words (Sachs, Weis, Zellagui, et al., 2008). Sass, Sachs, Krach, and Kircher (2009) found that thematic relations activated left superior and middle temporal regions, whereas taxonomic relations activated primarily right-lateralized frontotemporal regions. They concluded that taxonomic relations require more effortful processing than thematic relations.

Kalenine et al. (2009) tested whether taxonomic and thematic processing differentially rely upon visual and motor representations, respectively. They hypothesized that taxonomic relations would selectively activate visual networks because they entail featural similarity, whereas thematic relations would selectively activate motor and spatial networks because they support actions. Using a matching task in which participants chose which of two pictures is "semantically related" to the target, they presented either a taxonomic or a thematic option with an unrelated option. In contrast to Sass et al.'s (2009) suggestion that taxonomic processing is more effortful, Kalenine et al. found that taxonomic options were identified more quickly than thematic options. Taxonomic categorization bilaterally activated the visual association networks in the cuneus and lingual gyrus of the occipital cortex, suggesting that taxonomic categorization does indeed rely upon visual processing. Thematic categorization bilaterally activated motor and spatial networks in the posterior middle temporal cortex and inferior parietal lobules.

In sum, there is not yet consensus on exactly which cortical structures and networks are required for which mode of processing, but it is clear that taxonomic and thematic processing may be selectively impaired and consistently activate distinct cortical networks. Much remains to be specified neurologically, but the dissociation of taxonomic processing from thematic processing appears incontrovertible.

3.2. Behavioral Dissociations

Purely behavioral studies of neurologically intact participants have also revealed many differences between taxonomic processing and thematic processing. Several studies have examined the thematic processing of poor readers and normal readers. Children with poor reading abilities are generally less skilled than normally reading children at thematically integrating textual information (Cain, Oakhill, & Elbro, 2003), but providing a thematic organizer facilitates text recall among poor readers (Risko & Alvarez, 1986). And among poor readers, stronger association between prime and target words facilitates lexical decisions for taxonomic pairs (e.g., TABLE → CHAIR) but not for thematic pairs (e.g., BEACH → SAND; Nation & Snowling, 1999).

Doughty, Lawrence, Al-Mousawi, Ashaye, and Done (2009) presented to schizophrenic (SZ) and control participants 45 objects from five taxonomic categories (i.e., animals, fruits, body parts, clothing, and transport), and they asked participants to sort them into groups that "go together." Whereas control participants tended to sort all items into their taxonomic categories, SZ participants were more likely to sort thematically. For example, one SZ participant who sorted MONKEY with the group of fruits explained thematically that "monkeys eat fruit." When subsequently asked to sort the items into taxonomic categories, however, most SZ participants correctly identified all category members. This study indicates that SZ individuals retain relatively normal taxonomic knowledge but exhibit a tendency for thematic processing. However, SZ patients are impaired at thematic sequencing of story events (Matsui et al., 2007). It may be that SZ individuals tend toward thematic processing, but have highly disorganized and idiosyncratic themes that tend not to conform to experimenters' expectations (see also Titone, Libben, Niman, Ranbom, & Levy, 2007).

In a study modeled after Davidoff and Roberson's (2004) procedure with aphasic patient LEW, Lupyan (2009) presented object triads from which normal undergraduates were asked to choose the one that does not belong. For example, given a triad of BEE, EAGLE, and OWL, the size oddball is BEE. Given a triad of PIG, PENGUIN, and ZEBRA, the color oddball is PIG. And given a triad of POTATO, BALLOON, and CAKE, the thematic oddball is POTATO. On half the trials of this oddball task, participants also rehearsed a string of nine digits (i.e., verbal interference), which they were later prompted to remember. Results are illustrated in Figure 3. Verbal interference significantly slowed detection of size and color oddballs but not thematic oddballs. Thus, like patient LEW, normal undergraduates exhibited impaired featural categorization but preserved thematic categorization.

Maki and Buchanan (2008) investigated the latent factors that contribute to the mental representation of word meanings. They submitted five measures of association, three measures of semantic features, and five measures of text-based co-occurrence for each of 629 word pairs to three different

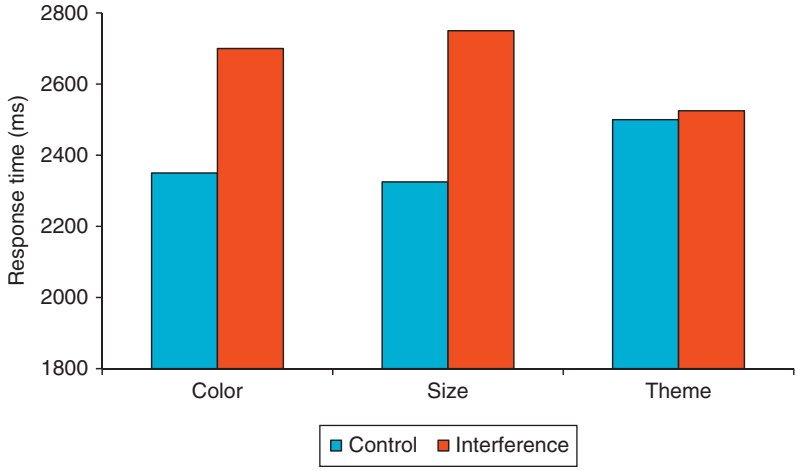

Figure 3 Response time to identify a color, size, or thematic oddball among a triad of objects, under normal (control) conditions or with verbal interference. Interference delayed identification of color and size oddballs, whereas identification of thematic oddballs was unimpaired. Results are extrapolated from Lupyan (2009).

statistical analyses (i.e., factor analysis, hierarchical clustering, and multidimensional scaling). Across analyses they found a three-factor structure consisting of separable associative, semantic, and thematic factors, akin to our typology of semantic relations illustrated in Figure 1. This suggests that association strength, semantic (i.e., taxonomic) similarity, and thematic relatedness independently contribute to word meaning.

Taxonomic processing and thematic processing can also elicit differential effects on other cognitive processes such as the apprehension of commonalities and differences. Because taxonomic categorization is based on a comparison process (see, e.g., Hampton, 2006; Markman & Wisniewski, 1997), inducing participants to compare objects is commonly assumed to evoke taxonomic processing. Inducing participants to integrate objects, in contrast, is assumed to evoke thematic processing. Estes (2003a) found that comparing concepts decreased participants' judgments of their similarity, whereas integrating concepts significantly increased judgments of similarity. That is, taxonomic processing and thematic processing, respectively, decreased and increased perceived similarity. Gentner and Gunn (2001) administered a difference listing task, in which participants were given limited time to list a single difference for as many concept pairs as possible. Prior to the difference listing task, participants either compared the concepts or integrated them. Participants listed significantly more differences for pairs that they had compared than for those they had integrated. In other words, relative to taxonomic processing, thematic processing inhibited the detection of

differences. Together these experiments reveal that thematic processing decreases perceived difference and increases perceived similarity (see also Golonka & Estes, 2009). Thus, numerous behavioral studies with normal participants have differentiated thematic processing from taxonomic processing.

4. Apprehension of Thematic Relations

Now that we have clearly defined what thematic relations are (i.e., spatial, temporal, causal, or functional relations between things that fulfill complementary roles) and what they are not (i.e., mere associations, scripts, *ad hoc* categories, or taxonomic relations), we will review how they are apprehended. To put it most simply, apprehending a thematic relation entails recognizing that the given concepts could perform different roles in the same scenario. This can be achieved by either retrieving a thematic relation from memory or generating one *ad hoc*. Conventional relations, such as that between a HAMMER and a NAIL or between a WINE GLASS and a DINNER PLATE (see Section 2.1), can be retrieved directly from memory. These concepts activate their typical roles, and the match between those roles determines whether and how they are thematically related (Estes & Jones, 2009). Unconventional thematic relations, such as that between a ROCK and a NAIL or between a WINE GLASS and COLA, must be generated *ad hoc*. Such unconventional relations between things arise from their affordances. For instance, a ROCK affords hitting a NAIL, and a WINE GLASS affords containing COLA. These affordances can be perceived directly (e.g., Gibson, 1979), which means that we can tell whether two things could plausibly be related thematically, even if we have no prior knowledge of a thematic link between them. In this section, we consider some basic properties of thematic integration (i.e., its uncontrollability and speed) and key factors of thematic processing (i.e., frequency and recency).

4.1. Uncontrollability

Thematic relations are intrusive. They are apprehended involuntarily in tasks for which they are irrelevant and even counterproductive. Bassok and Medin (1997) observed that, when instructed to justify their similarity ratings, participants frequently referred to thematic relations rather than features of the individual stimuli. In a more direct investigation of this phenomenon, Wisniewski and Bassok (1999) showed that not only does thematic processing intrude on a taxonomic task (i.e., similarity ratings) but also that taxonomic processing intrudes on a thematic task (i.e., thematic relatedness ratings). In fact, several other studies have confirmed that

thematic relations intrude on similarity judgments (Estes, 2003a; Gentner & Brem, 1999; Golonka & Estes, 2009; Jones & Love, 2007; Simmons & Estes, 2008). These studies are described in more detail in Section 5.1. Golonka (2008) tested whether participants are capable of ignoring thematic relations when judging similarity. Despite instructions not to base their ratings on thematic relations, participants' similarity ratings nonetheless exhibited a thematic effect of approximately the same magnitude.

Ross and Murphy (1999) tested whether thematic information is automatically activated in tasks such as similarity judgments and category decisions. Providing a thematic category label (e.g., "breakfast foods") increased the similarity of thematically related foods (e.g., BACON and EGGS), and reading a thematic prime (e.g., "The bagel was what he had when he woke up") facilitated category decisions about those foods (e.g., "is a bagel a breakfast food?"). The finding that thematic labels and primes affected similarity and categorization, respectively, suggests that such thematic information might not be automatically activated under normal (unprimed) circumstances. In contrast, taxonomic primes had no influence on similarity ratings or category decisions, whereas *ad hoc* category primes induced even larger effects on similarity and categorization. Thus, relative to taxonomic and *ad hoc* categories, thematic knowledge appears to be moderately activated in similarity and categorization tasks.

Gentner and Brem (1999) used a matching task (see Figure 2) in which a taxonomic option was paired with either a thematic option (i.e., conflict trial) or an unrelated option (i.e., taxonomic trial). For instance, the base GARLIC was presented with ONION (taxonomic) and either VAMPIRE (thematic) or CEMENT (unrelated). Participants were instructed to identify the taxonomic option. The rationale was that if thematic relations intrude on taxonomic processing, then participants should exhibit more errors on conflict trials than on taxonomic trials. Indeed, thematic options did intrude on taxonomic processing, as evidenced by more errors on conflict trials.

Lin and Murphy (2001) used a matching task with conflict trials, and they asked participants to choose the option that "goes with" the base "to form a category" (Experiment 1) or to choose the two options that "best form a category" (Experiment 2). Participants also were given a definition of "category" that emphasized taxonomic relations. In other studies, participants were instructed to treat the stimuli like representatives of their categories rather than as individuals (Experiment 4), and to justify their choices (Experiment 5). Nevertheless, across studies, participants tended to choose thematic options more often than taxonomic options (see also Murphy, 2001).

In another study, Lin and Murphy (2001, Experiment 10) used a speeded categorization task in which participants read a category label (e.g., "animal") followed by two simultaneously presented options. Participants' task was to decide whether either option was a member of the target category. On

critical trials, one of the options belonged to the category (e.g., DOG) and the other option was either thematically related to that alternative (e.g., LEASH) or unrelated (e.g., NEST). They found that thematic relations facilitated taxonomic categorization. For instance, participants responded that DOG is a member of "animal" more quickly when paired with LEASH than with NEST. Lin and Murphy, like Gentner and Brem (1999), concluded that thematic relations have a fast and automatic influence on taxonomic categorization.

Estes and Jones (2009; see also Jones, 2010) showed that a target word is recognized faster after a thematically related prime word (e.g., SOUP → CAN) than after an unrelated prime (e.g., COW → CAN). We referred to this effect as *integrative priming*, because the prime and target concepts were integrated into a single entity (i.e., the word pair denotes a single referent, rather than two independent referents). In subsequent experiments, we also embedded the thematically related word pairs in a list that included either many other thematically related pairs (e.g., BIRTHDAY → CANDLE) or many thematically unrelated pairs (e.g., LIMB → CANDLE). The rationale was that if thematic relations were apprehended voluntarily, then integrative priming should only be observed in the list with many thematic pairs. That is, if thematic integration was under participants' strategic control, then it should not occur in the list with few thematic pairs, because a strategy of thematic integration would rarely succeed in that list. Contrary to this prediction, however, integrative priming was observed across both lists with equal magnitudes (see also Coolen, van Jaarsveld, & Schreuder, 1991). In all of these studies, thematic relations intruded on other cognitive processes (e.g., similarity judgments, categorization, and word recognition) despite being irrelevant to the task.

4.2. Speed

Thematic relations appear to be apprehended relatively rapidly. As described in the preceding section, Gentner and Brem (1999) observed interference on a taxonomic categorization task from a thematically related distracter, relative to an unrelated distracter. In fact, to test whether thematic intrusions primarily occur early or late in processing, Gentner and Brem required participants to identify the taxonomic option within either a 1-s or a 2-s response deadline. Results are illustrated in Figure 4. Thematic distracters induced more errors than unrelated distracters at both deadlines, thus indicating that thematic relations are detected early (i.e., 1 s or less; see also Lin & Murphy, 2001, Experiment 10). Interestingly, the magnitude of this thematic intrusion decreased from 16% to 10% from the 1-s deadline to the 2-s deadline.

Chwilla and Kolk (2005) created story-like scripts by presenting simultaneously two unassociated words (e.g., DIRECTOR and BRIBE) followed by a third word (e.g., DISMISSAL). Critically, the first two words could either

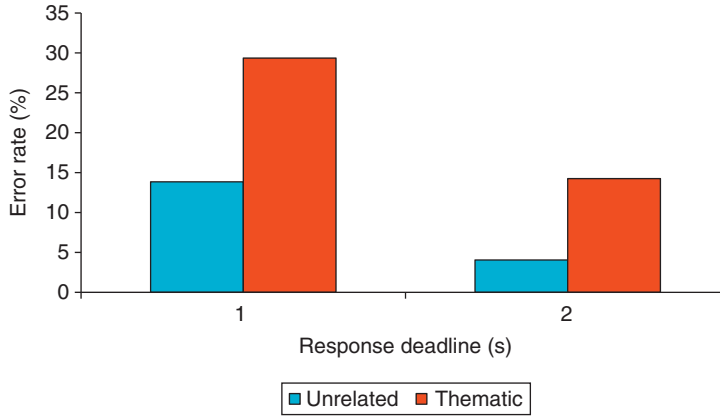

Figure 4 Error rates on the matching task at 1-s and 2-s response deadlines. Taxonomic options were paired with either an unrelated option or a thematic option. Thematic options induced more errors than unrelated options at both deadlines. Results are extrapolated from Gentner and Brem (1999).

establish a thematic context for the third word (as in the above example) or they could be unrelated. Across both a lexical decision task and a plausibility judgment task, the thematically related triads elicited faster responses than the unrelated triads. Moreover, the thematically related triads also elicited a smaller N400 effect than unrelated triads. This decreased N400 effect from thematic triads suggests that, given two components of a thematic scenario, participants expected the third concept to also relate thematically. It further indicates that whether the third concept is thematically related to the preceding two concepts can be apprehended in as little as 400 ms (see also Metusalem, Kutas, Hare, McRae, & Elman, 2010).

Estes and Jones (2009) directly compared lexical decision times for target words (e.g., CAN) preceded by a prime word that was thematically related (e.g., SOUP), taxonomically related (e.g., JUG), or unrelated (e.g., COW). To compare the time courses of thematic processing and taxonomic processing, we also manipulated the duration between presentation of the prime and target words (i.e., stimulus onset asynchrony or SOA). Results are illustrated in Figure 5. Across SOAs of 100, 500, 1500, and 2500 ms, the thematic and taxonomic primes facilitated recognition of their target words relative to the unrelated primes. However, at no point did the magnitude of the priming effect differ between the thematic and taxonomic conditions. This result has two implications of relevance to our purposes here. First, thematic relations were apprehended rapidly enough to facilitate word recognition when the delay between prime and target onset was only one-tenth of a second. Furthermore, these thematic relations were apprehended just as rapidly as taxonomic relations.

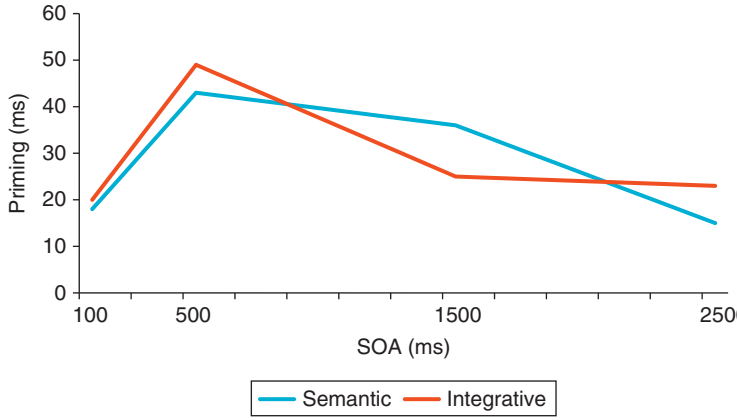

Figure 5 Semantic and integrative priming effects (i.e., baseline RT—experimental RT) across stimulus onset asynchronies (SOA). Both semantic and integrative priming were evident by 100 ms, asymptoted around 500 ms, and persisted to 2500 ms. At no point did the magnitudes of semantic priming and integrative priming diverge. Results are extrapolated from Estes and Jones (2009).

Studies comparing comprehension times for word pairs that are understood by inferring either a thematic relation (e.g., ONION TEARS) or a common feature (e.g., VAMPIRE INSECT) have found that thematic pairs are actually understood more quickly than feature-based pairs (Estes, 2003b; Gagné, 2000). This finding is consistent with Sass and colleagues' (2009) suggestion that taxonomic relations require more effortful processing than thematic relations. However, many of the featural pairs used in those studies were more akin to metaphors than to taxonomic pairs (e.g., Estes, 2003a, 2003b; Estes & Glucksberg, 2000), so they are more suggestive than conclusive of a thematic processing advantage. Indeed, in their comparison of thematic choices and taxonomic choices in the matching task, Kalenine and colleagues (2009) found that the taxonomic options were identified more quickly. Thus, much evidence indicates that thematic relations are apprehended relatively rapidly, though it is not yet clear exactly how rapidly.

4.3. Frequency

A given concept tends to perform the same role across various contexts, and people are implicitly aware of these thematic roles. For instance, people know from experience that PAPER is often written on. Less often, however, PAPER is also used for making things (e.g., AIRPLANES) and covering things (e.g., GIFTS), among other roles it may serve. Thus, with experience concepts acquire a frequency distribution of thematic relations. We are

implicitly aware that PAPER is most frequently written on, is slightly less frequently used to make or cover things, even less frequently causes cuts, and never eats animals. These *relation frequencies* affect thematic processing in an adaptive way. Whenever we encounter an object, a person, or a concept with which we have sufficient experience, that thing's frequent relations are activated. Effectively, encountering a familiar concept automatically activates the other concepts with which it is most likely to interact or co-occur, thereby facilitating perception of and responding to those thematically related concepts. Note also that relation frequencies are specific to individual concepts. The subject of a cutting theme is more likely to be a KNIFE than a PAPER, so that thematic relation is more frequent for KNIFE than for PAPER. However, things are very rarely written with knives, so the writing theme is more frequent for PAPER than for KNIFE.

Gagné and Shoben (1997) demonstrated that people know and use these relation frequencies. In a language comprehension study, they presented word pairs that could be thematically integrated by either a highly frequent relation (e.g., PAPER NOTE) or a less frequent relation (e.g., PAPER CUT), and they asked participants to judge as quickly as possible whether the word pair made sense as a phrase. The phrases were understood more quickly when they instantiated a highly frequent relation than an infrequent relation (see also Gagné & Spalding, 2004; but see Maguire, Devereux, Costello, & Cater, 2007). Storms and Wisniewski (2005) replicated this relation frequency effect in the Indonesian language, which differs fundamentally in structure from English, thus revealing that the effect is a general cognitive phenomenon rather than a language-specific idiosyncrasy. Even 4- to 5-year-old children, who possess relatively limited linguistic experience, are able to use relation frequencies in interpreting word pairs (Krott, Gagné, & Nicolades, 2009).

Maguire, Maguire, et al. (2010) and Maguire, Wisniewski, and Storms (2010) demonstrated that relation frequencies are constrained by the semantic categories (or features) of the given concept and that thematic integration depends on the interaction of the two concepts' categories. For example, LEATHER most frequently serves a compositional role, acting as the substance of which other objects consist. When thematically integrating LEATHER with another concept, then that frequent composition relation is activated. However, some phrases such as LEATHER NEEDLE entail a relation other than composition. This case illustrates the interactive nature of thematic integration: although a NEEDLE cannot be made of LEATHER, LEATHER NEEDLE is nevertheless understood relatively fast because the semantic categories of the two concepts mutually constrain the apprehension of a sensible thematic relation. Thus, the features of a concept constrain the thematic roles that it tends to instantiate, thereby producing a distribution of more and less frequent thematic roles for each concept with which we have sufficient experience. Our implicit statistical knowledge of these relation frequencies guides the apprehension of thematic relations.

4.4. Recency

Just as the frequency of a thematic relation affects processing, so does its recency. Both children (Smiley & Brown, 1979) and adults (Wisniewski & Love, 1998) are more likely to apprehend thematic relations after a series of other thematic relations than after a series of taxonomic relations. For instance, DOG KENNEL (habitation) is understood faster after OFFICE PLANT (spatial) and WIND EROSION (causal) than after OSTRICH BIRD (taxonomic) and DESK BED (taxonomic). More specifically, even a single thematic relation can facilitate the comprehension of a subsequent relation. For example, DOG KENNEL is understood faster after DOG HOUSE than after DOG FOOD because the first two both instantiate a habitation relation, whereas the third instantiates a different relation (Gagné, 2001).

Gagné (2001) initially obtained this relation recency effect only when the same modifier noun was used in both the prime and the target word pairs (e.g., DOG HOUSE → DOG KENNEL) and not when the modifiers differed (e.g., DOG HOUSE → CAT KENNEL). However, much subsequent research has revealed that relation priming can in fact be obtained with entirely different and unrelated concepts. For example, despite having no lexical overlap from prime to target, BEAR CAVE facilitates comprehension of BIRD NEST because both use the habitation relation (Estes, 2003b; Estes & Jones, 2006; Spellman, Holyoak, & Morrison, 2001).

In an innovative demonstration of this recency effect without lexical repetition, Raffray, Pickering, and Branigan (2007) used a picture matching task in which ambiguous target phrases could be understood in either of two possible ways. For instance, participants were prompted to decide whether a DOG SCARF matched a picture of a dog wearing a scarf (possessor relation) or of a scarf with a dog pattern on it (descriptor relation). These ambiguous targets were preceded by a prime trial that was unambiguously understood by one of those two relations, such as a rabbit wearing a T-shirt (possessor) or a T-shirt with a rabbit pattern on it (descriptor). Participants more frequently matched the ambiguous targets to the picture depicting the same relation as the prime than to the other relation.

Hristova (2009) also demonstrated the recency effect in an innovative paradigm. She preceded a thematically related target pair (e.g., BACTERIUM : INFECTION) with a prime pair that used either the same thematic relation (e.g., ACID : CORROSION) or a different relation (e.g., FILTER : WATER). One of the concepts in each pair appeared in either red or green font (the other appeared in black), and critically, the colors of the prime and target were either congruent (i.e., red → red or green → green) or incongruent (i.e., red → green or green → red). Participants' task was to identify the color of the font for each word pair. Results are illustrated in Figure 6. When the prime and target appeared in the same color (i.e., congruent trials), relation recency (i.e., same relation) facilitated responding. But when the prime and

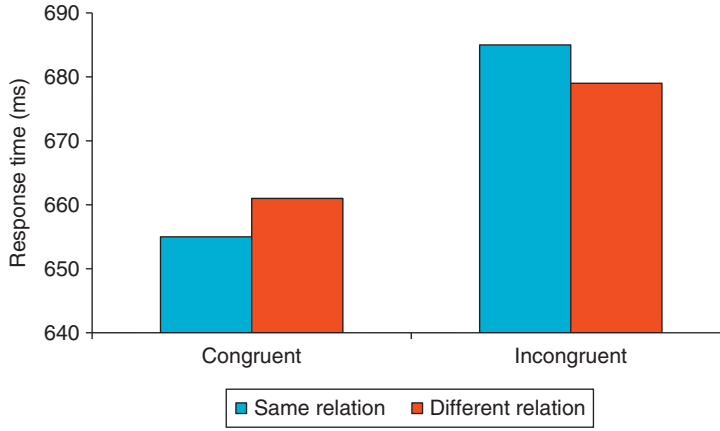

Figure 6 Response time to identify the color of a target word pair that instantiates either the same or a different relation from a prime, and that appears in the same (congruent) or a different color (incongruent) from the prime. Repetition of the target thematic relation facilitated responding on congruent trials but hindered responding on incongruent trials. Results are extrapolated from Hristova (2009).

target appeared in different colors (i.e., incongruent trials), relation recency actually slowed responding. Evidently, participants apprehended the thematic relations, and if the prime and target instantiated the same thematic relation, participants expected the words to be of the same color. Hristova thus demonstrated the relation recency effect in a paradigm for which thematic relations were irrelevant and, on most trials, counterproductive. Collectively, the findings described above indicate that thematic relations are apprehended uncontrollably and relatively quickly according to their frequency and recency of use.

5. Consequences of Thematic Relations for Cognition

Thematic relations are central to many cognitive processes. In this section, we focus on a few basic processes for which thematic relations have particularly profound effects.

5.1. Similarity

Traditional models of similarity, such as the contrast model (Tversky, 1977) and the structural alignment model (Gentner & Markman, 1997; Markman & Gentner, 2000), explain similarity only in terms of comparison: To

determine the similarity between two things, we compare them, identify their commonalities and differences, and weigh them accordingly. However, to the extent that other cognitive processes are shown to affect perceived similarity, these comparison models may fail to predict similarity judgments and related behaviors such as categorization, preferences, and decisions. Thematic relations reliably affect perceived similarity. To illustrate, consider LEMONADE, COFFEE, and MILK. Pause for a moment to judge which two of these concepts are most similar.

All three are drinkable liquids, but of course they differ in taste. They also vary in color and typical serving temperature. LEMONADE and COFFEE differ markedly in both color and typical serving temperature, as do MILK and COFFEE. In contrast, LEMONADE and MILK are both typically served chilled, and they differ only minimally in color. Thus, by feature comparison models such as the contrast model and the structural alignment model, LEMONADE and MILK should be judged most similar. Remarkably, though, MILK and COFFEE are actually judged most similar, despite having the fewest features in common. Why? COFFEE and MILK are perceived to be similar because people often drink them together. More generally, such thematically related concepts are judged more similar than thematically unrelated concepts (Golonka & Estes, 2009; Simmons & Estes, 2008; Wisniewski & Bassok, 1999).

Essentially, there are two main sources of similarity. Feature comparison, which is achieved by a process of structural alignment (Markman & Gentner, 2000), reveals the degree of featural commonality between objects or concepts. Thematic relations provide an additional source of similarity. By comparing MILK and COFFEE, we discover their common liquidity, drinkability, and so forth, which endow MILK and COFFEE with some degree of similarity. By thematically integrating MILK and COFFEE, we apprehend their complementary participation in the same scenario, and this boosts their similarity even further. This distinction between feature comparison and thematic integration gives rise to a two-dimensional model of similarity, which for simplicity is conceptualized as a 2 (taxonomic similarity: high, low) × 2 (thematic similarity: high, low) similarity space (Wisniewski & Bassok, 1999). Taxonomically similar concepts can be either thematically related (e.g., MILK and COFFEE) or unrelated (e.g., MILK and LEMONADE), and taxonomically dissimilar concepts can also be either thematically related (e.g., MILK and COW) or unrelated (e.g., MILK and HORSE).

In a seminal demonstration of this thematic effect, Wisniewski and Bassok (1999) had participants rate the similarity of concepts that varied orthogonally in taxonomic category membership (C+, C−) and thematic relatedness (T+, T−). For example, SHIP was compared to TUGBOAT (C+T+), CANOE (C+T−), SAILOR (C−T+), and SOLDIER (C−T−). They found that participants consistently rated T+ concepts as more similar than T− concepts. This was even true when the concepts were from the same

taxonomic category. To illustrate, SHIP was rated more similar to TUGBOAT than to CANOE (see also Golonka & Estes, 2009).

A valid criticism of this result is that because different concepts were used across conditions (e.g., TUGBOAT appeared in the C+T+ condition only), the difference in perceived similarity could be attributable to some factor other than thematic relatedness. However, subsequent experiments have established that the exact same concepts are judged more similar when participants thematically integrate them than when participants only compare their features. Estes (2003a) found that thematically integrating concepts (e.g., interpreting DOCTOR LIBRARY as a library for doctors) increases their perceived similarity, relative to a condition where the same items were not integrated prior to the similarity judgment. This suggests that it is the act of thematic integration, rather than a preexisting association, that increased their perceived similarity. Jones and Love (2007) also found a causal effect of thematic integration on similarity. In their experiment, participants judged similarity according to participation in the same thematic context. For instance, participants selected SHEEP as more similar to COLLIE than to GERMAN SHEPHERD when those concepts (i.e., SHEEP and COLLIE) occurred in the same thematic sentence (e.g., "The collie herds the sheep") rather than in separate, unrelated sentences (e.g., "The German shepherd herds the sheep" and "The collie chases the cat").

Wisniewski and Bassok (1999) argued that whether one compares or thematically integrates a pair of concepts depends upon the compatibility between the stimuli and the processes. A good proxy for featural commonality is taxonomic category membership. Concepts or objects that belong to the same taxonomic category tend to share more commonalities (Hampton, 2006; Mervis & Rosch, 1981) and have more differences related to these commonalities (Markman & Wisniewski, 1997; Pothos & Chater, 2002) than concepts or objects from different taxonomic categories. Wisniewski and Bassok argued that the characteristics of taxonomically related concepts make them highly compatible with the comparison process. For example, MILK and COFFEE are both members of the "beverage" category because they share important commonalities (e.g., liquidity, potability). Comparing MILK and COFFEE draws attention to differences that are related to these commonalities (e.g., caffeine content, taste, and typical serving temperature). These differences are highly informative and can influence how we interact with those objects. For example, one might choose to have MILK instead of COFFEE before going to bed. In such cases, the process of comparison helps to identify salient properties. MILK and COW, however, are difficult to compare because, like all taxonomically unrelated concepts, they have very few properties in common (Markman & Wisniewski, 1997). Furthermore, the differences that result from the comparison of these concepts are relatively uninformative (Wisniewski & Bassok, 1999). Participants who are asked to compare such concepts often simply state the categories to which

each belongs (e.g., "milk is a beverage, cow is an animal"). Wisniewski and Bassok (1999) argued that concepts from different categories are not compatible with the comparison process, which requires some basic level of commonality between concepts (see also Bassok & Medin, 1997). Taxonomically unrelated concepts are compatible with thematic integration, however. Because thematic relations occur between concepts that perform different roles, things that share few commonalities are actually easier to thematically integrate than concepts that share many properties. That is, having few commonalities provides an opportunity for different concepts to complement one another thematically. In contrast, taxonomically related concepts tend to have too many commonalities to perform different roles in the same theme.

Thus, stimulus compatibility drives process selection (Wisniewski & Bassok, 1999). Two key empirical results support this argument. First, stimulus compatibility explains the tendency to thematically integrate disparate concepts that share no preexisting thematic relation. Both Wisniewski and Bassok (1999) and Bassok and Medin (1997) reported that participants spontaneously generate thematic relations between taxonomically unrelated items. For instance, when asked to describe the similarity between PEDIATRICIAN and CAT, people often respond with statements such as "a pediatrician might own a cat." These results indicate that, when faced with incomparable stimuli, participants attempt to thematically integrate them. From this perspective, the intrusion of thematic relations on similarity and categorization tasks (Section 4.1) can be interpreted as evidence for a mismatch between task and stimuli. Similarity tasks are intended to tap the comparison process. But if the given stimuli are difficult to compare (e.g., if they are taxonomically unrelated), then participants thematically integrate them instead.

Second, as illustrated in Figure 7, thematic relations have a particularly large effect on the similarity of taxonomically unrelated concepts (Golonka & Estes, 2009; Wisniewski & Bassok, 1999). Golonka and Estes (2009) found that thematically related concepts from different taxonomic categories (e.g., SHIP and SAILOR) are judged to be much more similar than thematically unrelated concepts (e.g., SHIP & SOLDIER). For these items, thematic relatedness explained a substantial proportion of the variance in similarity ratings. In contrast, thematically related concepts from the *same* taxonomic category (e.g., SHIP and TUGBOAT) are judged to be only slightly more similar than thematically unrelated concepts (e.g., SHIP and CANOE). For these items, featural commonality explained the majority of the variance in similarity ratings. To provide another example, MILK is judged much more similar to COW than to HORSE, but MILK is judged only slightly more similar to COFFEE than to LEMONADE. Both COW and COFFEE receive a boost in similarity to MILK due to their respective thematic relations, but that boost is larger for COW because there is little other basis on which to judge its similarity to MILK. In contrast, COFFEE and MILK have many features in

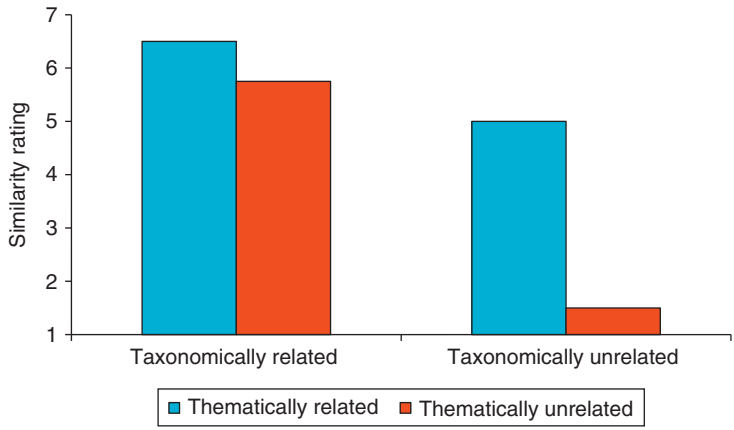

Figure 7 A typical result illustrating the influence of thematic relations on similarity ratings, with a larger effect among taxonomically unrelated stimuli than among taxonomically related stimuli. Results are extrapolated from Wisniewski and Bassok (1999) and Golonka and Estes (2009).

common, and hence their already-high similarity is boosted only slightly by their thematic relation. The effect of thematic relations on perceived similarity is thus moderated by the concepts' taxonomic relatedness: taxonomically similar concepts are easily compared and this comparison identifies relevant differences between them. Taxonomically dissimilar concepts are difficult to compare, thus leading participants to thematically integrate them instead (Wisniewski & Bassok, 1999).

Collectively, these studies reveal that people spontaneously apprehend thematic relations when judging similarity, and these thematic relations affect similarity judgments. This thematic influence on similarity is particularly pronounced among stimuli that are otherwise difficult to compare (see Figure 7).

5.2. Memory and Categorization (Conceptual Organization)

A tremendous amount of research demonstrates that conceptual knowledge is organized, to a large extent, around thematic relations. Evidence of conceptual organization derives primarily from studies showing that thematic relations aid memory and strongly affect categorization. Of particular interest in this area of research has been a claim that conceptual organization changes across the lifespan. Specifically, some have argued that thematic thinking dominates in early childhood, but then becomes secondary to taxonomic thinking in later childhood and into middle adulthood, and finally thematic thinking resuming its dominance in later adulthood (e.g., Smiley & Brown, 1979; see also Nelson, 1977). The cognitive transition in

childhood, known variously as the "thematic-to-taxonomic shift" and the "syntagmatic-paradigmatic shift," has been demonstrated across several memory and categorization paradigms. However, much of that research has been extensively criticized on methodological grounds, and the transition back to thematic thinking in older adulthood is less well researched. Below we summarize this literature.

It has long been known that participants spontaneously organize items both taxonomically and thematically during free recall (e.g., Jenkins & Russell, 1952), and that thematic relations facilitate the learning and memory of texts and stories (e.g., Bower et al., 1979; Seifert, McKoon, Abelson, & Ratcliff, 1986). Indeed, much research has demonstrated that when a to-be-remembered list includes words related to a given theme (e.g., THREAD, SEW, SHARP), people often incorrectly remember reading the theme word (NEEDLE; Deese, 1959; Roediger & McDermott, 1995). Ross and Murphy (1999) found that undergraduates spontaneously classify foods via both thematic categories (e.g., breakfast foods) and taxonomic categories (e.g., "vegetables"). Both taxonomic and thematic relations may facilitate memory by evoking greater elaboration during encoding and/or by acting as retrieval cues during recall. For example, Jones, Estes, and Marsh (2008) showed that individual words (e.g., FISH) are more likely to be recalled when the same thematic relation is instantiated at study and at test (e.g., FISH TANK → FISH POND) than when a different relation occurs at test (e.g., FISH TANK → FISH FOOD). These studies indicate that thematic relations are a salient way to categorize and remember objects.

Lucariello and Nelson (1985) presented 3- and 4-year-old children with two lists, each consisting of nine words for later recall. A taxonomic list consisted of three words from three taxonomic categories (animals, foods, and clothes), and a thematic list consisted of three words each from three thematic categories (zoo animals, lunch food, and clothes put on in the morning). Words on the thematic list were more likely to be recalled, suggesting that thematic relations aid very young children's memory more than taxonomic categories. Using a matching task (see Figure 2), Waxman and Namy (1997) asked 2-, 3-, and 4-year-old children to choose the option that "goes best with" or that "goes with" a base concept (e.g., DOG). Whereas the 2- and 3-year olds exhibited no clear preference between taxonomic (another dog) and thematic (BONE) options, the 4-year-olds consistently chose the thematic option (see also Blanchet, Dunham, & Dunham, 2001). Several other studies have also found that young children tend to choose a thematic option over a taxonomic option (Lucariello & Nelson, 1985; Nelson & Nelson, 1990), and this thematic preference remains relatively constant from 4 to 7 years of age (Lucariello, Kyratzis, & Nelson, 1992).

However, thematic thinking subsequently appears to decline. Siaw (1984) presented to younger (7-year-old) and older (10-year-old) children

a set of items that could be grouped either taxonomically or thematically. For example, BUS was included with four other items reflecting a school theme (CLASSROOM, PENCIL, STUDENT, and SWEATER) and four items from the "vehicles" category (CAR, TRUCK, TRACTOR, and WAGON). Siaw examined whether participants were more likely to recall the target item (BUS) along with other members of the school theme or along with other members of the "vehicles" category. The words were less likely to be clustered thematically than taxonomically during recall, and such thematic clustering was more common among the younger children than among the older children.

To investigate the presumed conceptual shift across the lifespan, Smiley and Brown (1979) administered a series of conflict trials in the matching task to very young children (4 years), young children (6 years), older children (10 years), young adults (20 years), and older adults (72 years). From the youngest to the oldest age groups, 65%, 70%, 15%, 5%, and 70% of participants exhibited a clear tendency for thematic choices. Examining the stability of this thematic preference in later adulthood, Pennequin, Fontaine, Bonthoux, Scheuner, and Blaye (2006) found that middle-aged (45 years) and older adults (71 years) both tended to choose thematic options over taxonomic options in the matching task. This nonmonotonic pattern demonstrates a strong preference for thematic thinking in early childhood, followed by a strong tendency for taxonomic thinking in later childhood and early adulthood, and finally a reemergence of thematic thinking in middle and late adulthood.

However, this developmental shift in conceptual organization has been the subject of much criticism. First, it should be noted that the thematic preference is observed only in particular tasks. Whereas choosing the option that "goes best with" the base tends to be thematic, choosing "another one" of the base tends to be taxonomic (Waxman & Namy, 1997). Likewise, asking participants to choose the picture "that is most like" the base elicits thematic choices, whereas asking them to choose the picture "that is the same kind of thing" elicits taxonomic choices (Deák & Bauer, 1995; see also Nguyen & Murphy, 2003). Second, participants' preferences in such matching tasks are also context dependent. Prior to a matching task, Blaye and Bonthoux (2001) showed 3- and 5-year-old scenes designed to prime either the thematic or taxonomic option. For example, when shown a picture depicting a circus theme, the children chose the thematic pair (TAMER and WHIP) as the best match for the target LION, but when shown a picture depicting a zoo, children chose the taxonomic pair (BIRD and GIRAFFE). Finally, many studies using the matching task have confounded the relation of the options (i.e., taxonomic vs. thematic) with their similarity to the base concept. For instance, the base DOG is more perceptually similar to the taxonomic option CAT than to the thematic option BONE. Indeed, in many of these studies the taxonomic option was not only a category comember with the base (e.g., DOG and CAT) but was actually another

version of the same item (e.g., another dog). Because the similarity of the options affects participants' choices (Markman & Hutchinson, 1984; Osborne & Calhoun, 1998), this prevalent confound renders equivocal many of the conclusions from the matching task.

Thus, if anything, the matching task appears to reveal a task-specific and context-dependent processing preference rather than a fundamental aspect of conceptual organization. The matching task is informative only if the options are equated on relevant factors such as their familiarity and attractiveness, and their perceptual similarity to and frequency of co-occurrence with the base. Unfortunately, such experimental controls have rarely been implemented in studies of this type. In contrast, the free association task may provide a simpler and more accurate measure of conceptual organization. Lucariello et al. (1992) used both a matching task and a free association task with 7-year-olds. Thematic responses were favored in the matching task in which they chose which option "goes with" the base, whereas taxonomic responses were more common in the word association task. This discrepancy across tasks provides further support for the conclusion that they reveal processing preferences rather than conceptual organization per se.

Borghi and Caramelli (2003) instructed children (5-, 8-, and 10-year-olds) to provide from 5 to 10 associated nouns or sentences for concepts representing nine different kinds, each of which included a superordinate (e.g., FURNITURE), basic-level (e.g., CHAIR), and subordinate (e.g., HIGHCHAIR) concept. Responses were coded as *taxonomic* if the associate was a superordinate, subordinate, or coordinate of the cue concept, and as *thematic* if the associate shared a locative (e.g., DOCTOR—"hospital"), temporal (e.g., "BIRD—spring"), action/event (e.g., BIRD—"fly"), or functional (e.g., CHAIR—"to sit on") relation. Attributive relations such as properties (e.g., CHAIR—"brown"), parts (e.g., BIRD—"beak"), and materials (e.g., CHAIR—"wood") were scored separately from the aforementioned thematic relations. Results are illustrated in Figure 8. The percentage of taxonomic responses was constant across the three age groups. Thematic responses were the most common, but they decreased across age groups. In contrast, attributive responses increased across ages. Results from the free association task thus indicate a preference for thematic thinking that slightly decreases across childhood.

In sum, people are naturally capable of both taxonomic and thematic thinking. Children appear to prefer thematic thinking, but with age, a tendency for taxonomic thinking emerges. However, the extent of this shift may have been overstated in early research, and the consensus is that people are equally capable of taxonomic and thematic thinking (Lin & Murphy, 2001; Nelson, 1977; Ross & Murphy, 1999; Smiley & Brown, 1979; Waxman & Namy, 1997). Priming paradigms such as the naming task and the lexical decision task provide an additional measure of conceptual organization, and as described next (Section 5.3), such studies corroborate the conclusion that thematic relations are highly accessible and influential in cognition.

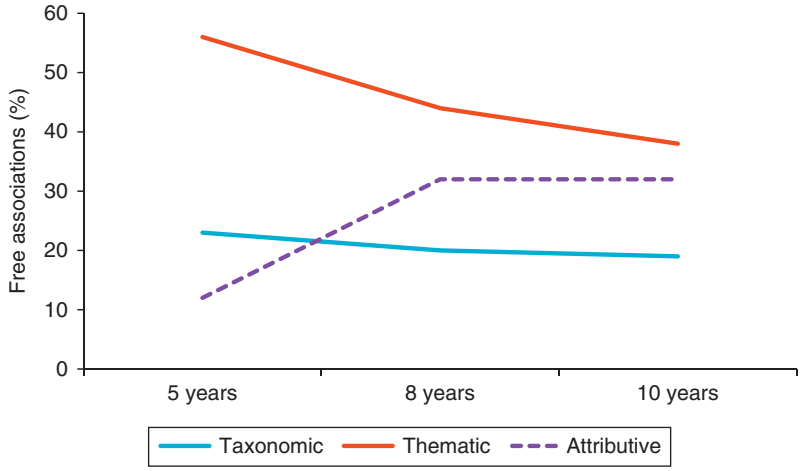

Figure 8 Taxonomic, thematic, and attributive responses in the free association task by 5-, 8-, and 10-year-old children. Whereas taxonomic associations remained constant across age groups, thematic associations decreased and attributive associations increased. Results are extrapolated from Borghi and Caramelli (2003).

5.3. Language

Thematic relations are essential to language comprehension on both local (e.g., word) and global (e.g., text passage) levels. As illustrated throughout Section 4 (see also Jones & Estes, in press), thematic relations facilitate the recognition and comprehension of individual words and word pairs. To reiterate, a target word is recognized faster after a thematically related prime (e.g., SOUP → CAN) than after an unrelated prime (e.g., COW → CAN; Estes & Jones, 2009; Jones, 2010), and word pairs are more quickly understood if they can be integrated with a thematic relation that has occurred either frequently (Gagné & Shoben, 1997; Storms & Wisniewski, 2005) or recently (e.g., Estes, 2003b; Estes & Jones, 2006; Gagné, 2001). Such thematic priming of language emerges early in childhood. Perraudin and Mounoud (2009) found that 5-year-old children exhibited a robust priming effect in a naming task for thematic word pairs with an instrumental relation (e.g., KNIFE → BREAD), but only a marginal effect for taxonomic word pairs (e.g., CAKE → BREAD). In contrast, 7- and 9-year-old children exhibited both instrumental and taxonomic priming. McCauley, Weil, and Sperber (1976) obtained a similar developmental trajectory with associated primes and targets, many of which were thematically related (e.g., BONE → DOG, NEEDLE → DOCTOR, MONKEY → BANANA, FLOWER → BEE), and such instrumental and script-based priming are also reliably observed among undergraduates (Hare et al., 2009; Moss et al., 1995).

In addition to word pairs, thematic integration also occurs among the subject, verb, and object of whole sentences. Nakano and Blumstein (2004) presented sentence frames in which the subject and verb could both be either real words or nonwords (e.g., "The *bartender/quajeter* is *kicking/thazing* out the . . ."). They then completed the sentence with either a word or a nonword at the final object position, and participants made lexical decisions to that final word/nonword. Relative to the nonword control sentences (e.g., "The quajeter is thazing out the"), prime sentences with real subject and verb words (e.g., "The bartender is kicking out the . . .") facilitated responses to target words (e.g., "drunk"), thus indicating facilitation of thematically related sentences. Relative to those control sentences, however, prime sentences with either a nonword subject (e.g., "The quajeter is kicking out the . . .") or a nonword verb (e.g., "The bartender is thazing out the . . .") failed to prime the target word (i.e., "drunk"). This latter finding demonstrates that neither the subject nor the verb alone was sufficient for thematic priming. Rather, priming was obtained only with the successive thematic integration of the subject, verb, and object.

When a global context conflicts with the local context, thematic integration will occur at the highest possible discourse level. Hess, Foss, and Carroll (1995) found that target nouns (e.g., "poem") were named faster following a thematically consistent local context (e.g., "The English major wrote the poem") than after a thematically inconsistent context (e.g., "The computer science major wrote the poem"). But when the thematically related local context followed a scenario in which the global context was thematically unrelated (e.g., a two-sentence description of an English major struggling with a computer science class), target naming times were determined by the global context rather than the local context. In an event-related potential study, Metusalem and colleagues (2010) presented a context story (e.g., playing in the snow) followed by a target word that was globally and locally congruent (e.g., building a SNOWMAN), globally and locally incongruent (e.g., building a TOWEL), or globally congruent but locally incongruent (e.g., building a JACKET). The latter condition is of particular interest here, as its global congruence is based on a thematic relation (i.e., between SNOW and JACKET). As expected, the N400 amplitudes, which are indicative of incongruence between a context and a target word, were large in the globally and locally incongruent condition and were small in the globally and locally congruent condition. Critically though, the globally congruent but locally incongruent words elicited N400 amplitudes of intermediate size. Thus, within 400 ms participants had detected the word's incongruence with the local context (i.e., building a JACKET), but that incongruence was ameliorated by the word's thematic congruence with the context (i.e., SNOW and JACKET).

As these studies illustrate, plausibility is crucial to thematic integration on both the local and global levels. For example, "The pirate terrorized the sailor" and "The sailor terrorized the pirate" are both syntactically clear and

straightforward, but because the former is more thematically consistent (i.e., plausible) than the latter, it is understood more quickly (e.g., Boland, Tanenhaus, Garnsey, & Carlson, 1995). Altmann (1999) demonstrated that we rely on our knowledge of plausible real-world events during the incremental integration of each incoming word of a sentence. Participants read target sentences (e.g., "He delivered some machine guns to the military base next door") after an antecedent sentence that rendered the target either plausible (e.g., "Hank parked his van outside the local military base") or implausible (e.g., "Hank parked his van outside the preschool nursery"). As they read the target sentence, participants judged whether each individually presented word continued to make sense. Even though the target sentence itself was entirely sensible, there were more "no" responses for the object of the verb (e.g., "machine" and "guns") following the implausible antecedent than the plausible antecedent. More locally, Costello and Keane (2000) included plausibility as one of only three major constraints on understanding pairs of individual words. Plausibility and its associated effects depend upon the thematic fit between the various constituents of the phrase, sentence, or passage (for models of plausibility see Connell & Keane, 2006; Padó, Crocker, & Keller, 2009).

Thematic fit is based on one's knowledge and real-world experience of objects and events (McRae, Spivey-Knowlton, & Tanenhaus, 1998), and consequently, thematic relations constrain the set of candidate words that are likely to follow a preceding word or context (McRae & Matsuki, 2009). For example, Hare and colleagues (2009) showed that object words are understood faster after their typical events (e.g., PICNIC → BLANKET), locations (e.g., GARAGE → CAR), and instruments (e.g., OVEN → COOKIES). Judgments of a target noun are also faster when presented with a verb that sets up a thematic context (e.g., PAYING → CUSTOMER and SERVING → CUSTOMER) than when presented with a thematically unrelated verb (e.g., GOVERNING → CUSTOMER). Such thematically constraining verbs also reliably prime their thematically related instruments (e.g., STIRRED → SPOON), but surprisingly, no priming occurs between verbs and thematically related locations (e.g., SWAM → OCEAN). Ferretti, McRae, and Hatherell (2001) argued that this selective priming of instruments but not locations indicates that thematic verbs more strongly constrain the set of prototypical instruments than the set of typical locations. For example, one most frequently stirs things with a SPOON, but one could swim in a number of locations (e.g., POOL, LAKE, RIVER, SEA, OCEAN). Ferretti, Kutas, and McRae (2007), however, found that thematic verbs did reliably prime their thematically related locations when the verb was in the past imperfect form (e.g., WAS SWIMMING → OCEAN) but not in the past perfect form (e.g., HAD SWAM → OCEAN). The imperfect aspect of the verb denotes an ongoing action, which renders salient its location. In contrast, the perfect aspect denotes a completed action, which evidently renders its location less relevant.

Thus, thematic relations facilitate comprehension of typical agents, patients, instruments, and locations of objects and events. It is no exaggeration to state that thematic integration provides the underlying mechanism by which language is understood. Without thematic integration, individual words could not be integrated into phrases, sentences, and entire texts or conversations.

5.4. Inference and Analogy

A rapidly growing body of research has begun to illuminate a deep relationship between thematic thinking and analogical reasoning. In addition, although relatively little research has examined the role of thematic relations in more basic inferential reasoning, preliminary results suggest that thematic thinking also supports some inferences.

Inference is typically based on taxonomic knowledge. For instance, the taxonomic knowledge that CRICKET is a sport allows one to validly infer, even if one is unfamiliar with the sport, that it requires physical effort and (often) results in a winner. However, thematic knowledge can also support inference. The thematic knowledge that CRICKET involves a BALL and a BAT allows one to infer that there must an athlete who delivers the ball (i.e., a BOWLER) and another who attempts to hit it (i.e., a BATSMAN). Lin and Murphy (2001) tested for thematic inference by presenting scenarios in which a base animal is related to another animal either thematically (i.e., they interact) or taxonomically. Critically, the base animal was described as having a particular bacterium, and participants judged whether the two other animals were likely to also have the same bacterium. People were more likely to infer that two animals have the same bacterium if those animals were thematically related than if they were taxonomically related (see also Saalbach & Imai, 2007, described in Section 6.2). This makes sense because bacteria are transmitted by proximity, and animals that interact with one another will have opportunities for contact. Chaigneau, Barsalou, and Zamani (2009) found similarly that the accuracy of inferences is improved when participants have knowledge about the events and situations in which objects are used. For example, participants more accurately inferred the function of a novel object when it was presented with other objects used in the same event (e.g., a projectile to be used in a catapult) than when presented in isolation.

Thematic relations also support analogical inference. Comprehending an analogy requires one to recognize the relation between two source concepts (e.g., PEN : WRITE) and infer that same relation between two target concepts (e.g., SCISSORS : CUT). Indeed, the relationship between thematic thinking and analogical reasoning appears to be strong and interactive. Doumas, Hummel, and Sandhofer (2008) developed a powerful computational model in which relational concepts (including thematic relations)

themselves are abstracted from experience with multiple instances of analogous relations. With sufficient exposure to various causal relations, for instance, one develops CAUSE and EFFECT role concepts, which are then used to more efficiently detect and represent new causal relationships. And conversely, because many analogies involve thematic relations, Leech, Mareschal, and Cooper (2008) developed another powerful computational model in which analogical reasoning develops from the more basic process of relation priming (see Section 4.4). Essentially, they argue that analogical inference is bootstrapped from our natural propensity for apprehending thematic relations. Thus, analogies appear to enable the development of relational themes, and those thematic relations subsequently sustain more advanced analogical inference.

Several studies support this presumed link between thematic thinking and analogical reasoning. Understanding an analogy activates the relation between terms (Green, Fugelsang, & Dunbar, 2006), and that relation can be recognized even after the terms have been forgotten (Kostic, Cleary, Severin, & Miller, 2010). Apprehension of the relation between source items not only facilitates relational transfer to a target pair (e.g., Bendig & Holyoak, 2009) but also facilitates retrieval of previously experienced, relationally similar examples (Gentner, Loewenstein, Thompson, & Forbus, 2009; Markman, Taylor, & Gentner, 2007). And just as literal similarity can either help or hinder analogical reasoning (Gentner & Colhoun, 2010), thematic relations can also facilitate a correct response or distract from it (Thibaut, French, & Vezneva, 2010). For example, the highly accessible thematic relation between TRAIN and TRACK induces the correct analogical inference in CAR : ROAD :: TRAIN : ??, but it decreases accuracy in CAR : PETROLEUM :: TRAIN : ??. In addition to the relation itself, the relational roles are also an important factor in analogical reasoning (Estes & Jones, 2008; Hummel & Holyoak, 1997, 2003; Morrison et al., 2004). Faced with the analogy WIND : EROSION :: SMOKE : ??, people tend to incorrectly complete the analogy with the highly accessible and thematically related FIRE. However, given that the direction of the causal relation in the source pair is cause → effect, a more appropriate response would be SUFFOCATION. Together, these studies suggest that thematic thinking underlies analogical inference and may also influence more basic inferences.

6. Individual Differences and Cultural Effects

Although thematic relations are apprehended quickly and automatically (Sections 4.1 and 4.2) from a very young age (Section 5.2), some individuals are more likely than others to think thematically, and some cultures exhibit more thematic thinking than others.

6.1. Individual Differences

Most people can easily identify thematic relations (see Section 5.2), but there are important and persistent individual differences in thematic thinking. Across multiple studies using the matching task with conflict trials (Figure 2), Simmons and Estes (2008) instructed participants to choose the option that is "most similar to" or most "like" the base concept. Regardless of the precise instruction, participants tended to choose either the taxonomic option across most trials or the thematic option across most trials. In other words, some participants consistently judged similarity on the basis of common features, while other participants consistently judged similarity on the basis of thematic relatedness. Individual variation in how strongly thematic relations affect similarity is quite robust. In a subsequent experiment, Simmons and Estes replicated these individual differences using another task (i.e., similarity ratings) and another set of items that were matched for several lexical variables (i.e., length, written frequency, forward and backward association, and lexical co-occurrence). Furthermore, Golonka and Estes (2009) showed that individual differences in the matching task strongly predict similarity ratings of an additional set of concepts. This indicates that the individual differences persist across tasks.

These results are also consistent with the categorization literature, which reports individual differences in the likelihood of forming thematic categories. Lin and Murphy (2001; see also Murphy, 2001) found considerable individual differences in the way participants grouped objects in the triad task. When selecting which option "Goes with [the base concept] to form a category," many participants choose a thematic option and many others choose a taxonomic option. Lin and Murphy replicated this basic finding with various instructions ("Which two of the three items form a category?"), stimuli (concept labels from Smiley & Brown, 1979), and tasks (speeded category judgments, novel property generalization). Thus, as with similarity judgments, there are pervasive individual differences in how strongly thematic relations affect categorization. Table 1 summarizes the percentages of participants who consistently chose taxonomic options or thematic options, as well as those who exhibited no consistent preference for either option-type, in the various studies by Lin and Murphy and by Simmons and Estes (2008). This table suggests two notable conclusions: (1) about 80% of the participants from these samples of North American undergraduates consistently chose either taxonomic or thematic options and (2) taxonomic thinking and thematic thinking were equally popular, with about 40% of the participants in each group.

Simmons and Estes (2008) further examined whether these individual differences were predictable. In addition to administering the matching task, they also measured individuals' enjoyment of thinking and problem solving (i.e., "Need For Cognition," NFC; Cacioppo & Petty, 1982), and they had

Table 1 Numbers of Participants Who Consistently Chose Taxonomic Options (Taxonomic) or Thematic Options (Thematic), or Who Exhibited No Consistent Preference for Either Option-Type (No Preference), in Conflict Trials of the Matching Tasks Administered by Lin and Murphy (2001) and Simmons and Estes (2008).

Source	Study	Taxonomic	No preference	Thematic
Lin and Murphy (2001)	1	11	0	21
	2	14	3	15
	3	2	10	6
	4	6	6	6
	5	1	13	6
	7	7	0	9
	8	7	3	6
Simmons and Estes (2008)	1a	11	8	16
	1b	11	4	20
	2a	30	4	21
	2b	20	4	8
	3	12	15	8
Combined	*N*	132	70	142
	%	38.37	20.35	41.28

Data for Experiments 7 and 8 from Lin and Murphy include the control condition only.

participants explicitly identify the factors that they considered relevant to similarity judgments. NFC and explicit beliefs both reliably predicted participants' similarity judgments. Specifically, a preference for thematic relations in similarity judgments was associated with low NFC and an explicit belief that participation in a common scenario is relevant to similarity. There thus appear to be two types of people who prefer thematic thinking to taxonomic thinking: those who do not particularly enjoy engaging in cognitive activities and those who hold a contextual conception of similarity.

Some evidence suggests that these individual differences emerge in childhood and reflect differences in language learning and play behavior. Waxman and Namy (1997) found consistent individual differences in thematic and taxonomic choices among 4-year-olds but not among 3-year-olds, indicating that such preferences for thematic thinking (or taxonomic thinking) emerge in early childhood. Dunham and Dunham (1995) found that children who engaged in object identity play (i.e., pointing to objects) and who used language referring to objects tended to categorize taxonomically. In contrast, children who engaged in relational identity play (i.e., focusing on interactions between objects) and who used language referring to the relations between objects tended to categorize thematically.

Such individual differences may also be related to formal education. As reported above, enjoyment of thinking and problem solving (i.e., high

NFC) is associated with a decreased likelihood of thematic thinking (Simmons & Estes, 2008). Older adults, who are far removed from formal schooling, are also more likely than younger adults and school-age children to classify on the basis of thematic relations (Annett, 1959; Overcast, Murphy, Smiley, & Brown, 1975; Smiley & Brown, 1979). Moreover, adults who have never participated in formal education also tend to categorize on the basis of thematic rather than taxonomic relations. Luria (1976, cited in Lin & Murphy, 2001) found that adults in rural Uzbekistan during the 1930s strongly preferred to sort items thematically. For example, they grouped AXE with TREE rather than SAW, and in fact they denied that AXE and SAW made any sense together. Formal education also predicted the extent of thematic categorization in a rural Mayan population in Mexico (Sharp, Cole, & Lave, 1979). When asked to sort pictures into groups of things that belong together, many participants sorted taxonomically (e.g., grouping all food items together). However, participants with less education tended to sort items into functional, thematic categories (e.g., a food item and a utensil).

Thus, there are strong and persistent individual differences in thematic thinking. These individual differences are evident in childhood, with formal education appearing to decrease the tendency for thematic thinking. To the extent that education is culturally mediated, then, cultural differences may also exist (e.g., rural Uzbekistan and rural Mexico). These possible cultural effects are examined further in the following section.

6.2. Cultural Effects

Although formal education appears to discourage thematic thinking (Section 6.1), this relationship may vary across cultures. Western cultures emphasize taxonomies by attending to objects and attributes, whereas East Asian cultures emphasize themes by attending to relations and contexts (Nisbett, 2003). To illustrate, Masuda and Nisbett (2001) had Japanese and American participants watch vignettes of a simulated aquarium scene. Afterward, participants recalled what they had seen, and their recognition memory was also tested. Japanese participants were more likely than American participants to recall inert objects (e.g., plants) and background elements of the aquarium, whereas American participants were more likely to recall large moving objects (e.g., fish). Japanese participants were less likely to recognize a previously seen fish if it was presented against a novel background, whereas American participants were unaffected by this change in context. Thus, Japanese participants paid more attention to context, while American participants focused on individual objects. So whereas formal education appears to inhibit thematic thinking in some cultures (Section 6.1), the predominance of thematic thinking among educated Japanese students reveals that thematic thinking is more likely to be mediated by culture than by education

per se. Indeed, thematic thinking seems to be more common among well-educated Chinese and Japanese than among well-educated Europeans and Americans. For example, Ji, Zhang, and Nisbett (2004) found that European Americans tended to group triads of objects using taxonomic relations, whereas Chinese preferred thematic categorization (see also Chiu, 1972).

Some research suggests that these differences arise from early socialization (Bornstein, Azuma, Tamis-LeMonda, & Ogino, 1990; Fernald & Morikawa, 1993). American parents emphasize object attributes, whereas Eastern parents emphasize relations. In a cross-cultural study of infant-directed language, Fernald and Morikawa (1993) observed differences in the way Japanese and American mothers speak to their children about an object of play (e.g., a toy dog). American mothers used more noun labels (object focused), while Japanese mothers used more onomatopoeic labels and social routines (relation focused). So, an American mother might describe a toy dog with "Look! It has four legs and a tail," whereas a Japanese mother might identify the dog with "Look! A Woof-woof. Hello, goodbye."

It should be noted that cultural differences in thematic thinking are not yet well understood. Across three different tasks Saalbach and Imai (2007) found inconsistent cultural effects. In a matching task, they found that Chinese participants and German participants did not differ in their preference for thematic and taxonomic options. In a similarity rating task, both groups rated taxonomic pairs (TOWEL and HANDKERCHIEF) to be more similar than thematic pairs (TOWEL and SHOWER), but the magnitude of this difference was greater for German than for Chinese participants, suggesting a greater differentiation of taxonomic and thematic relations among the Germans than among the Chinese. In an induction task (e.g., what is the likelihood that TOWEL and HANDKERCHIEF carry the same bacteria?), however, German participants thought that taxonomic and thematic pairs were equally likely to carry the same bacteria, whereas Chinese participants judged that taxonomic pairs were more likely to share the bacteria. Thus, the categorization task exhibited equivalent preferences for thematic grouping, the similarity task exhibited greater differentiation among German participants, and the induction task exhibited greater differentiation among Chinese participants. So thematic thinking may vary across cultures, but thematic and taxonomic relations are both evident across cultures.

Interestingly, language also appears to mediate thematic thinking within a given culture. Ji and colleagues (2004) compared grouping on the matching task by Chinese students who were exposed to English very early in schooling (i.e., from Hong Kong and Singapore) to those who were exposed to English in secondary school or later (i.e., from Mainland China and Taiwan). Regardless of when they learned English, the Chinese students were more likely than American students to categorize thematically. However, depending on the Chinese students' age of English acquisition, their categorization was affected by the language in which they were

tested. Specifically, the Chinese students who acquired English early in life were equally likely to group the objects thematically when tested in Chinese and in English. The Chinese students who acquired English later in life, though, were more likely to group taxonomically when tested in English than in Chinese. These results suggest that culture and language have unique and independent effects on thematic categorization.

In summary, the consensus is that individual and cultural differences in thematic thinking reflect subtle biases in people's tendency to attend taxonomic or thematic relations rather than large differences in conceptual knowledge (Lin & Murphy, 2001; Simmons & Estes, 2008; Smiley & Brown, 1979). However, these individual and cultural differences reflect more than a fleeting preference. The tendency to use thematic relations in similarity and categorization is related to stable phenomena such as NFC (Simmons & Estes, 2008) and cultural norms (Chiu, 1972; Ji et al., 2004), and it is predicted by language learning (Dunham & Dunham, 1995; Ji et al., 2004) and formal education (Luria, 1976; Overcast et al., 1975; Sharp et al., 1979).

7. Conclusion

In this section, we highlight some areas that we consider important topics for further research, and finally we conclude by summarizing the current state of knowledge on thematic thinking and by considering its role in cognition more generally.

7.1. Future Directions

The current knowledge of thematic thinking has come almost entirely from basic cognitive research. Although this approach may be optimal for understanding the properties and processes of thematic thinking, it yields an unnecessarily limited understanding of the practical implications of thematic thinking. We suggest that thematic thinking is now well enough understood to begin supplementing the basic cognitive research with more applied research. Here we describe some recent investigations of thematic thinking in just two applied domains, but we hope that future studies will address other practical implications.

Thematic relations have profound effects on social cognition. For instance, social interactions can be considered thematic relations because they are external (i.e., they arise between two or more people) and complementary (i.e., people typically play reciprocal roles in interactions). The quality of social relations affects attitudes toward members of social or cultural groups, as formalized in intergroup contact theory (Allport, 1954; Crisp & Turner, 2009; Pettigrew, 1998; Stathi & Crisp, 2008; Turner, Hewstone, & Voci, 2007; Turner, Hewstone, Voci, Paolini, & Christ, 2007). Positive

interactions between members of different social, religious, and ethnic groups decrease prejudice (Allport, 1954; Pettigrew, 1998; Pettigrew & Tropp, 2006), for instance, by increasing positive intergroup attitudes (Stephan & Rosenfield, 1978) and by decreasing anxiety (Voci & Hewstone, 2003). Negative interactions, in contrast, decrease liking (Allport, 1954). The intergroup contact effect is robust enough that even *imagining* contact with an outgroup member seems sufficient to decrease prejudice (Stathi & Crisp, 2008; Turner, Crisp, & Lambert, 2007). Social thematic relations thus are powerful moderators of intergroup attitudes. It is likely that thematic relations, in the form of social interactions and relationships, also moderate many other social behaviors involving similarity, categorization, and inference. We view this as a particularly fertile area for more applied research.

Thematic relations are also likely to emerge as an important factor in management and marketing research, which is currently dominated by taxonomic thinking. Corporate executives, new product developers, and brand managers are trained not to stray beyond the firm's taxonomically defined "core competence." Hence, the current practice is to acquire taxonomically similar companies (e.g., Kraft's 2010 acquisition of Cadbury), to rejuvenate old products by simply adding taxonomically related features (e.g., camera phones), and to extend one's brand only to taxonomically related products (e.g., BMW motorcycles). Quite recently, however, a trend has appeared for thematic relations in management. FedEx acquired Kinko's because their two services complemented one another (i.e., print and ship services), Nike+ integrates Nike running shoes with the Apple iPod (i.e., many people listen to music while exercising), and several sports brands such as Adidas have recently extended into the deodorant market (i.e., exercise causes sweat, which requires deodorant). In fact, research indicates that consumers actually prefer new products that are taxonomically dissimilar but thematically related (Gibbert & Mazursky, 2009; Gill & Dube, 2007). Thus, we anticipate not only a rapid growth of research on thematic relations in management and marketing but also an increase in thematically related practices in the marketplace.

We are ourselves beginning to investigate various applications of thematic thinking in both marketing (e.g., thematic brand extensions and hybrid products) and social cognition (e.g., how social relations affect similarity judgments and group membership). Thematic thinking certainly has strong implications for many other applied domains, which we are optimistic will be advanced theoretically with continued research.

7.2. Conclusions

The current state of knowledge on thematic thinking is diverse and well developed. The main conclusions of our review are the following:

- By virtue of their externality and complementarity, thematic relations are distinct from mere association, scripts, *ad hoc* categories, and taxonomic categories (Section 2; see also Figure 1).
- Themes and taxons constitute different modes of thought, as evidenced by numerous neuropsychological and behavioral dissociations of thematic thinking and taxonomic or categorical thinking (Section 3).
- Thematic thinking typically occurs uncontrollably and quickly, and is guided primarily by the frequency and recency of experience with specific thematic relations (Section 4).
- Thematic thinking has cascading effects on many basic cognitive processes, including similarity, categorization, memory, language, inference, and analogy (Section 5).
- People are naturally capable of thematic thinking. This capacity emerges early in childhood and is maintained throughout adulthood. Even when a preference for taxonomic thinking is evident, the capacity for thematic thinking remains undiminished (Sections 4 and 5.2).
- The propensity to think thematically varies considerably across individuals and cultures. Such variation appears to result from interactions between language, formal education, and cultural norms (Section 6).
- Thematic thinking complements rather than displaces taxonomic thinking. The two modes of thought develop separately, entail distinct processing mechanisms, and contribute uniquely to cognition. Together they provide a more coherent, cohesive, and complete view of cognition.

In sum, we have considered what thematic relations are, how they are apprehended, and how they affect cognition. Without such thematic thinking, models of cognition will remain categorically limited.

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