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# Constructing Meaning

Seana Coulson
*Cognitive Science Department*
*University of California, San Diego*

This article reviews cognitive neuroscience research on visual and language processing to suggest an analogy between the neural interpolation mechanisms in perceptual processing and the constructive processes that underlie meaning construction in language. Traditional models of language comprehension as a decoding process are argued to involve an overattribution of the import of linguistic information, and an overly narrow view of the role of background and contextual knowledge. A review of a number of event-related brain potential (ERP) studies of language comprehension reveals an early sensitivity in the brain response to global contextual factors. These findings are consistent with a view of linguistic information as prompting meaning construction processes such as the activation of frames, the establishment of mappings, and the integration or blending of information from different domains.

One need look only as far as the nearest newspaper to see examples of figurative language. For instance, a quick survey of the BBC World Web site revealed the following headlines.

RIOT ERUPTS IN FRENCH CITY CENTRE (XXXXX, XXXX)
BURKINA FASO POISED FOR ELECTIONS (XXXXX, XXXX)
MERKEL DEFENDS GERMAN REFORMS (XXXXX, XXXX)

Although not particularly poetic, each of these contains a metaphoric verb. A riot, for example is not the sort of thing that literally explodes, and thus *"erupts"* is figurative. A nation cannot meaningfully be said to be balanced or hovering, and consequently *"poised"* is figurative. Further, because reforms cannot literally be said to be safe from harm, the act of *"defending"* them is a metaphoric one.

Correspondence should be addressed to Seana Coulson, Cognitive Science Department, University of California, San Diego, Dept. 0515, 9500 Gilman Drive, La Jolla, CA 92093. E-mail: coulson@cogsci.ucsd.edu

The skeptic, of course, might wonder whether headlines, because they are intended to efficiently convey the gist of a story, are more metaphoric than other language. However, consider the first two sentences from the article about Merkel:

> Germany's Chancellor-designate Angela Merkel has called on Germans to make sacrifices to help reverse the economy's 'downward trend'. Unveiling the details of a coalition agreement, Mrs. Merkel said Germans would have to tighten their belts (XXXXX, 2005).

Several cases of conventionalized figurative language are present in this excerpt. In the first sentence, for instance, the BBC describes economic events in terms of spatial motion—in this case, *"downward"* motion is used to characterize unfavorable economic events. In the second sentence, previously unknown information is *"unveiled,"* an instantiation of the entrenched *"KNOWING IS SEEING"* mapping (e.g., Lakoff & Johnson, 1999; Sweetser, 1990). Further, the metonymic idiom *"tighten their belts"* is employed. Figurative language, it would seem, is all around us.

Yet, despite the growing consensus that metaphor, and indeed figurative language more generally, is a pervasive aspect of everyday language (e.g., Gibbs, 1994; Lakoff & Johnson, 1980), this knowledge has had relatively little effect on the way language researchers think about language, and even less effect on how most go about their work. Recent reviews of the cognitive neuroscience of language barely touch on figurative language, focusing instead on the neural substrate of word, sentence, and text processing (Gernsbacher & Kaschak, 2003; R. Martin, 2003). Indeed, when cognitive neuroscientists have addressed this aspect of language, they have overwhelmingly targeted the contribution of the right hemisphere (see, e.g., articles in the forthcoming special issue of *Brain and Language* on figurative language comprehension).

Although it is important to learn what brain structures participate in the processing of figurative language, ideally cognitive neuroscience has more to offer metaphor scholars than a list of brain areas. Perhaps, rather than just assigning cognitive processes to brain regions, the cognitive neuroscientist can also address the hard problem and aim to integrate her general knowledge of neurophysiology with processing models of figurative language comprehension. In an attempt to achieve a deeper understanding of this important phenomenon, I will relate some findings from cognitive neuroscience to figurative language comprehension.

In particular, I suggest an analogy between the neural mechanisms that subserve perceptual processing and those that underlie meaning construction in language. Folk models of vision involve a passive registration process in which people record optical information that exists in the world. However, as understood by modern neuroscientists, visual processing is an active, constructive process in which people exploit optical information to interact with the world. Similarly, whereas folk models of language comprehension portray it as a decoding process for deriving propositions about the world, research in linguistics suggests a complex interplay between linguistic and nonlinguistic knowledge in the construction of meaning (Sperber & Wilson, 1995). It is important for researchers in figurative language to move beyond the old folk models, embrace the constructive nature of meaning, and to situate their work as central in the study of language, and indeed to the larger enterprise of cognitive neuroscience.

The section on VISION gives a brief overview of neuroscience research on the visual system, and reveals a complex interdependence between bottom-up and top-down processing in this domain. In the section on LANGUAGE COMPREHENSION, I review event-related brain potential (ERP) language research that points to a similar context-sensitivity in language as observed in visual processing. Because all models posit a role for background knowledge in language comprehension, I go on to contrast these proposals with common assumptions in language research. In the section on CREATIVITY, I argue that traditional models underestimate the creative nature of meaning construction processes, and point to examples that suggest that people frequently combine knowledge structures in ways that do not conform to the constraints of the real world. The final section outlines the space structuring model of meaning construction and points to research on metaphor comprehension consistent with that approach. Overall, my goal is to show how the study of figurative language might benefit from knowledge about brain function and its role in other complex cognitive activities.

## VISION

I begin with the visual system because it is perhaps the best understood system in the brain. In fact, a large proportion (20–30%) of the human brain is dedicated to visual processing, as the visual system includes the entire occipital lobe, the infero-temporal cortex, the posterior aspect of the parietal lobe, and even a portion of the frontal lobe. It can be divided into a large number of areas based on a combination of anatomical and functional criteria. One traditional view is that each area functions as an independent module with a specialized processing role, such as the computation of visual form, color, or motion. For example, early visual areas such as V1 and V2 have neurons that are differentially sensitive to aspects of shape such as the orientation of a line, neurons in V4 are differentially sensitive to color, and neurons in area V5 (also called MT) are differentially sensitive to moving stimuli.

One of the most basic concepts in the organization of the visual system is the notion of a receptive field. A neuron's receptive field is the region of space where stimulation results in a change in its firing pattern. For example, each cell in the retina has a cone-shaped receptive field in three-dimensional space, and a small circular region in any given plane. When an object in the visual world falls within that cell's receptive field, it stimulates the cell and causes it either to speed or slow its firing rate. Although the receptive field of retinal cells, such as rods and cones, is directly dependent on their location in the eye, the receptive field of neurons in the brain depends on their connection to other cells.

## Classical Models

A prevailing model of visual processing posits hierarchical stages of visual analysis beginning at the retina and ending at the hippocampus. Hubel and Wiesel (1968) suggested an exclusively feedforward model in which information was transmitted from the retina to the thalamus to V1, V2, and V3, although the modern conception of visual processing is considerably more complicated (see Van Essen & Gallant, 1994, for review). On the classic Hubel and Wiesel model, interactions of cells at one level in the hierarchy affect receptive field characteristics of cells at higher levels. In fact, a given neuron can integrate information from different cells that it connects to, so that its responses differ in important ways from those in its input. For example, simple cells in primary visual cortex (V1) exhibit orientation selectivity by responding to bars of a particular preferred orientation (e.g. horizontal bars), a property absent from responses in the thalamus or retina.

This hierarchical proposal is supported by a number of findings from the study of the visual system in animals, especially the macaque monkey. First, there are a large number of feedforward connections between visual areas (Felleman & Van Essen, 1991), as would be needed for a system in which information from one area is passed on to the next area in the hierarchy. Receptive fields in low level areas are much smaller than those in higher level areas (Maunsell & Newsome, 1987). The latency of neural responses to visual stimuli is shorter for low level visual areas such as V1 than for high level areas in the temporal lobe (Mendola, 2003). Moreover, whereas low-level areas such as V1 and V2 respond to meaningless stimuli that encroach on their receptive fields, higher level areas frequently respond only to particular categories of stimuli, such as faces (Van Essen & Gallant, 1994), consistent with the idea that higher-level areas code for increasingly complex features.

## Context Sensitivity in Vision

Although the traditional model of visual processing is adequate as a broad-brush account, more recent research has shown that a number of its fundamental assumptions are overly simplistic, and underestimate the complexity of neural interactions and the resultant dynamicity of neural computation. For example, whereas early accounts involved mainly feed-forward connections, neuroanatomical studies have revealed the presence of a large number of ‘backward“ connections from higher-level areas to lower-level ones, as well as lateral connections between cells at the same level in the hierarchy. Further, rather than being simple feature detectors, cells in visual areas are often sensitive to a variety of attributes. Moreover, even the receptive field, the atomic unit of the visual system is far more dynamic and changeable than previously believed. Although it was long assumed that receptive fields remained constant over the life of the cell, it turns out that the response to stimuli inside a cell's classical receptive field can be modulated by stimuli outside it, a property known as context sensitivity (Pessoa & DeWeerd, 2003). For example, if the receptive field and its surrounding area are masked and the background is stimulated for a short period of time, the receptive field of the cell will "expand" and begin responding to visual stimuli adjacent to the masked area (Gilbert & Wiesel, 1992).

Another example of the context sensitivity of the visual system is the phenomenon of color constancy, or the fact that the perceived color of objects remains the same in different lighting conditions. Land (1959) provided a dramatic demonstration of color constancy using spatially complex stimulus patterns called *Mondrians* after the artist who inspired them with his paintings of colored rectangles. Participants were shown a Mondrian display illuminated by three colored lights and asked to adjust their intensity until the center patch appeared white. When the lights were moved to illuminate an adjacent rectangle, participants reported that the patches retained their original coloration despite the large changes in the intensity and spectral distribution of the light. In fact, a number of perceptual phenomena are context dependent, including things such as depth planes, coherent motion, and texture contrast (see Spillman & Werner, 1996, for a review).

## Constructive Nature of Visual Processing

It is interesting that the context sensitivity of the visual field is thought to be related to another important characteristic of the visual system, its constructive nature. One classic example of the brain's propensity to go beyond the input is its ability to ignore the blind spot. The blind spot is the region of the retina where the optic nerve attaches and, consequently, there are no receptors. Assuming that conscious perceptual experience results from the transduction of physical energy in the receptors, it would seem that the blind spot would produce a small hole in the visual field, reflecting the absence of visual information from that region (Brewster, 1832). Instead, people experience perceptual completion, the sensation of visual phenomena in a region of the visual field from which they get no physical information.

One explanation for perceptual completion is that it reflects a neural filling-in process that is part of normal object recognition processes. Indeed, the blind spot, construed as a region of the world from which we have little information, can be understood as one case of a more general problem. Although we blink approximately every 5 sec, causing a 250 ms interval with no visual input, we typically do not experience any perceptual discontinuity. Further, objects in the world are often obscured by other objects, leading to an incomplete projection of that object's surface onto the retina.

The visual system exploits various interpolation mechanisms to infer the presence of contours and surfaces to compensate for the incompleteness of input infor-

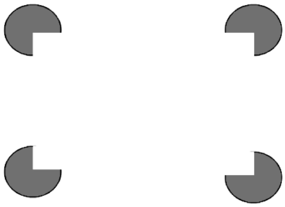

FIGURE 1 Kanizsa rectangle.

mation. The existence of these mechanisms is supported by visual illusions such as that in Figure 1 which, rather than being experienced as four "Pac-Man" shapes on a white background, is typically seen as a rectangle resting on four circles. The inside of this *Kanizsa rectangle* is usually experienced as being brighter than the outside, and the apparent brightness transition is seen as an illusory contour (Kanizsa, 1976). Because the perceptual completion occurs in the same (visual) modality as the perception of the figure, this phenomenon is known as modal completion.

Studying neural responses in monkeys, von der Heydt (1984) found evidence of V2 cells whose firing rate was greatest under conditions most conducive to the perception of illusory contours. Peterhans, von der Heydt, and Baumgartner (XXXX) suggested that these V2 neurons are driven by traditional edge-detection cells, as well as by cells that multiplicatively integrate stimuli oriented orthogonally to the contour (corners). Because V2 neurons are understood as coding for actual contours, this finding is often thought of as reflecting the neural filling-in process that underlies perceptual completion phenomena. Indeed, evidence suggests that all contours—be they real or illusory—coded for in V2 are treated similarly in subsequent visual processing (see Lesher, 1995).

Moreover, the mechanism that underlies the perception of illusory contours is only one of at least three different interpolation methods thought to be used in the visual system. Besides the use of convergent feed-forward projections, other mechanisms include the recruitment of lateral connections and re-entrant projections from higher levels using synchronization (see Spillman & Werner, 1996). In short, there are multiple interpolation mechanisms operating at varying levels of visual processing—including very early, low-level processing, as well as high-level object and scene recognition processes—suggesting visual processing is fundamentally constructive. In fact, interpolation may be thought of as an important aspect of neural processing more generally considered, suggesting that it is an important factor in cognitive processes besides vision.

## LANGUAGE COMPREHENSION

Although not as well understood as the visual system, the neural processes underlying language comprehension have also been found to be context sensitive and constructive. The main way that the real-time comprehension of language materials has been studied is with ERPs, because they provide an ongoing record of brain activity related to various kinds of sensory, motor, and cognitive processing events. The physical basis of the ERP signal is the fact that when large groups of neurons (on the order of hundreds of thousands) fire simultaneously, they create an electrical field in the brain that can be detected at the scalp via the electroencephalogram (EEG). The ERP is obtained by applying electrodes to the scalp, recording participants' EEG, and averaging across events within experimental categories. The averaging process presumably cancels out the EEG that is not related to the experimenter's categories so that the remaining signal represents the brain activity related to the processing of the experimental stimuli. By comparing the ERPs to different sorts of stimuli, the researcher can assess how changing the nature of the cognitive task modulates the brain response.

## Context Sensitivity in Language Comprehension

In a classic ERP language experiment, Kutas and Hillyard (1980) contrasted ERPs elicited by visually presented sentences that ended congruously, as in Example 1a, with ERPs elicited by sentences that ended incongruously, as in Example 1b.

(1a) I take my coffee with cream and SUGAR.
(1b) I take my coffee with cream and DOG.

They found negativity in the brainwaves that was much larger for incongruous sentence completions than the congruous ones. Because it peaks about 400 ms after the onset of a visually presented word, this negativity is called the N400.

Because the N400 was initially reported as a brain response to incongruous sentence completions (Kutas & Hillyard, 1980, 1984), some people mistakenly believe it is only elicited by semantic anomalies. However, research indicates it is a far more generally elicited ERP component associated with the integration of a word into the established context (Kutas, Federmeier, Coulson, King, & Munte, 2000). In fact, N400 is elicited by all words spoken, signed, or read, and its size or amplitude is an index of the difficulty of lexical integration. The best predictor of N400 amplitude is a word's cloze probability in a particular sentence, namely, the probability that participants will generate a given word in a sentence completion task. Consequently, N400 is small for high cloze (predictable) completions such as SUGAR in Example 1a, large for low cloze completions such as DOG in 1b, and intermediate in amplitude for sentence final words of intermediate cloze probability.

Interestingly, N400 effects register both linguistic and nonlinguistic expectancies. Hagoort, Hald, Bastiaansen, and Petersson (2004) recorded ERPs as people read sentences such as "Dutch trains are … " that ended either as expected ("yellow"), with a semantic violation ("sour"), or with an ending that was false ("white"). Although there is no semantic anomaly in saying that trains are white, the Dutch participants in this study all knew that Dutch trains are actually yellow. Because the violations occurred at different levels of linguistic structure, Hagoort and colleagues predicted that the semantic violations would elicit a different sort of ERP effect from the pragmatic violations of real world knowledge. However, both sorts of violations elicited N400 components with similar onset and offset latency, as well as a similar topography across the scalp. These findings suggest that semantic and pragmatic information were brought to bear over the same time course, and engaged similar brain regions during the time window in which the N400 was generated. Note, however, that other aspects of the EEG elicited by the two violation types suggested that the brain may keep a record of the source of processing difficulty.

ERP research suggests that the processing difficulty of a given word depends on its predictability in the sentence in which it appears. Moreover, the brain regions that underlie the N400 component do not seem to differentiate between predictability based on linguistic knowledge, such as what sorts of adjectives can predicate trains, or real world knowledge, such as what color trains in The Netherlands are. In fact, Van Berkum, Berkum, Hagoort, and Brown (1999) have found that words that elicit N400s of approximately equal amplitude in an isolated sentence do not elicit equivalent N400s when they occur in a text that makes one version more plausible than another.

For instance, as the completion of “Jane told her brother that he was exceptionally … ,” the words “quick” and “slow” elicit similarly sized N400 components. However, when the same sentence was preceded with “By five in the morning, Jane’s brother had already showered and had even gotten dressed,” “ … exceptionally SLOW” elicits a much larger N400 than “ … exceptionally QUICK.” As in vision, local language processing is affected by contextual factors, in this case consistency with the situation described in the preceding sentence.

## Local and Global Contexts

Moreover, just as feature detection in vision relies on processes for global context detection, there is reason to believe that word comprehension also relies on contextual factors. For example, it is impossible to understand the meaning of *weekend* without an understanding of the structure of the week, as well as the cultural knowledge that many people in industrialized countries work Monday through Friday, and not on Saturday and Sunday (Fillmore, 1976). This context dependence in meaning has been explored in frame semantics, a research program in cognitive linguistics in which a word’s semantic properties are described with respect to how they highlight aspects of an associated frame, or structured set of background assumptions. Langacker (1987) argued that although *roe* and *caviar* refer to the same thing, their meanings differ because *roe* presumes a biological frame and *caviar* presumes a culinary one. Conversely, Lakoff (1987) argued that the different meanings of *mother*, as in “my birth mother” versus “my adopted mother”, each rely on different frames for parenthood.

The interrelationship between local and global semantic processing was supported by research conducted by St. George, Mannes, and Hoffman (1994). These investigators recorded participants’ ERPs as they read ambiguous paragraphs that either were or were not preceded by a disambiguating title. For example, people read paragraphs like the following (adapted from Bransford & Johnson, 1972),

> The procedure is actually quite simple. First you arrange items into groups. Of course one pile may be sufficient depending on how much there is to do. … After the procedure is complete one arranges the materials into different groups again. Then they can be put in their appropriate places. Eventually they will be used once more and the whole cycle will have to be repeated. …

The title for this example is “Washing Clothes” and provides the reader with information about the appropriate frame to activate. Prior research with these materials had shown that people both understood the paragraphs better and were better able to remember their contents when they were preceded by titles than when they were not (Bransford & Johnson, 1972). St. Georges and colleagues (1994) found that words in the untitled paragraphs elicited greater amplitude N400 than the same words in titled paragraphs. Although the local contextual clues provided by the paragraphs were identical in the titled and untitled conditions, ERPs revealed real-time processing differences in their lexical integration. These findings suggest that activating the frame facilitated the comprehension of these materials.

## Shifting Contexts

The study of joke comprehension also addresses the importance of frames for language comprehension, because many jokes are funny because they deceive the listener into using the wrong frame to help interpret the information presented in the first part of the joke. For example, consider the following joke, “I let my accountant do my taxes because it saves time: last spring it saved me 10 years.” Initially, the listener activates a busy professional frame. However, at the punchline “saved me 10 years,” it becomes apparent that a crooked businessman frame is more appropriate. Although lexical reinterpretation plays an important part in joke comprehension, to truly appreciate this joke it is necessary to recruit background knowledge about particular sorts of relationships that can obtain between business people and their accountants, so that the initial busy professional interpretation can be mapped into the crooked businessman frame. The semantic and pragmatic reanalysis to understand jokes like this is known as frame shifting (Coulson, 2001).

Given the impact of frame shifting on the interpretation of one-line jokes, one might expect the underlying processes to be reflected in the brain’s real-time response. Coulson and Kutas (2001) compared ERPs elicited by sentences that ended as jokes that required frame shifting with unfunny "straight" endings consistent with the contextually evoked frame. Two types of jokes were tested, high constraint jokes such as Example 2, which elicited at least one response on a sentence completion task with a cloze probability of greater than 40%, and low constraint jokes like Example 3, which elicited responses with cloze probabilities lower than 40%. For both Examples 2 and 3, the word in parentheses was the most popular response on the cloze task.

(2) I asked the woman at the party if she remembered me from last year and she said she never forgets a (face 81%).
(3) My husband took all the money we were saving to buy a new car and blew it all at the (casino 18%).

To control for the fact that the joke endings are (by definition) unexpected, the straight controls were chosen so that they matched the joke endings for cloze probability, but were consistent with the frame evoked by context. For example, the straight ending for Example 2 was "name" (the joke ending was "dress"); the straight ending for Example 3 was "tables" (the joke ending was "movies"). The cloze probability of all four ending types (high and low constraint joke and straight endings) was equal, and ranged from 0–5%.

Coulson and Kutas (2001) found that ERPs to joke endings differed in several respects from those to the straight endings, depending on contextual constraint as well as participants' ability to get the jokes. In good joke comprehenders, high but not low constraint joke endings elicited a larger N400 than the straight endings. This effect can be seen as similar to the N400 effect observed by St. George and colleagues (1994) in the comparison of ERPs to words in titled and untitled paragraphs. Just as the activation of the frame facilitated the lexical integration of words in titled relative to untitled paragraphs, it facilitated lexical integration of the high constraint straight endings relative to the jokes. Similar effects may have been absent from the low constraint stimuli, because those sentences led to the activation of a diverse set of frames that were less likely to be consistent with the straight ending.

However, both sorts of jokes (high and low constraint) elicited a late positivity in the ERP (500–900 ms postonset), as well as a slow sustained negativity (300–900 ms postonset), evident over left frontal sites. The effect at left frontal sites has been suggested to reflect the manipulation of information in working memory (Coulson & Kutas, 2001; Coulson & Lovett, 2004). The late positivity is an ERP effect often associated with the activation of information in memory (i.e., retrieval), consistent with the suggestion that joke comprehension requires the activation of a novel frame.

In poor joke comprehenders, jokes elicited negativity between 300 and 700 ms after the onset of the sentence final word. The absence of the late positivity and the left frontal negativity in the poor comprehenders' ERPs suggests that these effects index cognitive operations that are important for actually getting the joke. The poor joke compehenders apparently searched for a coherent interpretation of the joke endings, but because they were unable to retrieve the frame necessary to get the joke, neither the late positivity nor the left frontal effect was evident in their ERPs.

These demonstrations of the brain's relatively early sensitivity to discourse-level manipulations are consistent with the dynamic inferencing mechanisms assumed in many frame-based models of comprehension. Based on computational considerations, Shastri (1999) proposed that frame-based inferences necessary for language comprehension occur in a time frame on the order of hundreds of milliseconds, consistent with observations that high-level manipulations begin to affect the ERPs 300 ms after the onset of a critical word (Coulson & Kutas, 2001; Coulson & Lovett, 2004). In such models, comprehension is achieved by binding elements of the discourse representation to frames in long-term memory (Coulson, 2001; Lange, 1989). Such models help explain how speakers are able to rapidly and routinely compute predictions, explanations, and speaker intentions (DeLong, Urbach, & Kutas, 2005; Shastri & Ajjanagadde, 1993).

## CREATIVITY

Cognitive scientists studying meaning have assumed many of the same sorts of ideas as those studying vision. For example, where vision scientists have assumed that perception involves a combination of low-level visual features into more complex object representations, language researchers have assumed that comprehension involves the combination of low-level meaning features into more complex sentence and discourse representations. However, this building block metaphor is as inadequate for language as it is for vision. As argued, two essential properties of neural activity in the visual system include its context sensitivity and its constructive nature, as the response of neurons is not to a particular sort of stimulus, but rather to a particular sort of stimulus in a context (Spillman & Werner, 1996).

Contrary to one's intuition, the visual information transduced by the eyes differs considerably from the information the brain subsequently computes from it. The constructive nature of visual processing can be seen as rooted in the fact that the world is far more complex than the incomplete optical information that reaches the retina. Cognitive linguists have argued for an analogous phenomenon in language in that information in the linguistic input considerably underdetermines its emergent meaning. On this perspective, speakers use language as a tool to activate information in their listener's knowledge base (Lee, 2002). Words and other sorts of linguistic structure are not intrinsically meaningful but are used by speakers to actively construct meaning.

As a result, a complex expression is often more specific than the meaning of its individual components, and can even conflict with those constituent meanings. Explaining this phenomenon, Langacker (2000) writes:

> when a novel expression is first used, it is understood with reference to the entire supportive context. The speaker relies on this context, being able to code explicitly only limited, even fragmentary portions of the conception he wishes to evoke. Usually, then, the expression's conventionally determined import at best approximates its actual contextual understanding. … It does not contain or convey the intended meaning, but merely furnishes the addressee with a basis for creating it. (p. 15)

## Common Assumptions in Language Research

The perspective previously outlined involves assumptions that differ somewhat from those traditionally made in psycholinguistics. For example, in a review of behavioral research on language comprehension, Clifton and Duffy (2001) discussed studies that address how people use prosodic, syntactic, lexical, and semantic structure, along with background and situational knowledge to understand sentences and texts. But rather than being construed as a resource for the creative construction of meaning, background knowledge is typically understood merely as a constraint on an otherwise independent comprehension process.

This view is so pervasive that even researchers with vastly different models of language comprehension assume meaning is encoded in the linguistic string, and that the primary role of background knowledge is to aid in the decoding process. For example, researchers with opposing models of word recognition agree that ultimately the proper meaning of an ambiguous word is determined by its plausibility in view of real world knowledge (c.f. Rayner, Binder, & Duffy, 1999; see also C. Martin, Vu, Kellas, & Metcalf, 1999). Similarly, whereas Clifton (2000) and Tanenhaus, Spivey-Knowlton, and Hanna (2000) had disparate views on how and when real world plausibility affects parsing, they agreed that world knowledge is an important source of constraint on the syntactic structure ultimately assigned to a string of words.

The construal of background and local context as constraints on meaning is problematic because it seems to presume that an unruly linguistic meaning requires context to keep it under control. However, background and contextual knowledge should not be viewed as constraining linguistic meaning, but rather as essential resources that make meaning possible. In this respect, the relationship between knowledge and meaning is analogous to that between waves and surfing. Waves do act as a constraint on the surfer's movements. But perhaps, more important, the wave is the setting for surfing, and is, in fact, a crucial component of the activity. Viewing knowledge as a constraint on meaning is not wrong, but rather unproductive and misleading.

A great deal of language research proceeds as if disambiguation were the main goal of language comprehension, views background knowledge as the ultimate arbitrator in parsing disputes, and generally treats the language user as an unimaginative automaton. In fact, people not only tolerate ambiguity in language; they positively revel in it. The pun, a genre of jokes in which multiple meanings for the same word are deliberately evoked, is one of the earliest forms of verbal humor in children. Indeed, adults often capitalize on contextually inappropriate but grammatically available alternative meanings for humorous intent (Clark, 1996; Curco, 1998; Drew, 1987).

## Transcending Ambiguity

Besides people's tolerance for ambiguity, most psycholinguists underestimate the human ability to suspend their beliefs about the physical and social world. Cereal advertisements feature a talking tiger that apparently eschews the life of a carnivore in favor of sugar-coated corn flakes. The coyote in the roadrunner cartoon can, at least momentarily, defy the laws of physics when he runs off the edge of a cliff. Dressed in a Spiderman suit, Peter Parker can swing from skyscraper to skyscraper, yet in his civilian clothes he has trouble wooing the girl of his dreams. Even children's books (or perhaps especially children's books) describe elephants who wear clothes, bears that go on adventures, multitalented bunnies, and imaginary creatures who speak in rhymes.

Indeed, recent research has suggested that language users are perfectly willing to attribute human-like characteristics to inanimate objects, and that doing so in the appropriate context poses no undue processing demands. Niewland and Van Berkum (in press) found that, out of context, sentences such as "The peanut was in LOVE" elicit larger N400s than sentences such as "The peanut was SALTY". However, the reverse pattern of effects was observed when the same sentences were embedded in a story context such as

> A woman saw a dancing peanut who had a big smile on his face. The peanut was singing about a girl he had just met. And judging from the song, the peanut was totally crazy about her. The woman thought it was really cute to see the peanut singing and dancing like that. The peanut was …

In the story context, "salty" elicited a larger N400 than "in love," suggesting the factual statement was more difficult to understand than the fictional one (Nieuwland & Van Berkum, in press).

The role real world knowledge plays in language comprehension is considerably more subtle and complex than generally acknowledged in psycholinguistics.

The personified peanut, for example, does not conform very well at all to one's knowledge of peanuts, but does conform to a western cultural model of a person in love. Similarly, Sinha (2005) argued that real world knowledge is an important prerequisite for understanding fictional discourse such as Conan Doyle's Sherlock Holmes stories. Quoting an excerpt in which Holmes asks Watson to bring his service revolver along on an expedition, Sinha noted that a proper understanding of this fictional discourse relies on the reader's knowing that it was quite common in 19th century England for retired military officers, such as Watson, to retain their guns for use in civilian life. Readers are not troubled by the interleaving of fact and fiction in stories about Sherlock Holmes. On the contrary, this forms an important component of their aesthetic appeal.

## Fictivity in Language

Indeed, explicitly fictional language is but one manifestation of an even more pervasive phenomenon of *fictivity*, as language is used to invoke virtual properties (see Pascual, 2002, for review). The paradigmatic example of fictivity in language is fictive motion. In fictive motion, forms that conventionally refer to motion are applied to static elements (Talmy, 2000). For example, the motion predicate "runs" is applied to a static blackboard in Example 4, and the motion predicate "stretches" is applied to a stationary mountain range in Example 5.

(4) The blackboard runs all the way to the wall.
(5) That mountain range stretches from Mexico to Canada.

Sentences 6–8 are examples of the related phenomenon of fictive or virtual change (Langacker, 1997).

(6) His newspaper column grew longer every week.
(7) The trees got shorter at higher altitudes.
(8) The water got deeper as he swam away from shore.

Moreover, Langacker (2003) argued that figurative phenomena such as fictive motion and fictive change rely on the capacity to evoke fictive entities, nonexistent objects such as the millionaire in Sentence 9 whose properties are nonetheless understood.

(9) Ursula wants to marry a millionaire but she'll never find one.

In Sentence 6, for example, a single (fictive) generic column can grow, even though none of its factive instantiations change. Change predicates can be applied to the noun phrases in Sentences 6–8 precisely because they refer to fictive entities rather than actual ones. Thus construed, reference to fictive entities is very common, occurring whenever speakers use the generic meaning of a noun (Langacker, 2000).

## SPACE STRUCTURING MODEL

The space structuring model is a model of language comprehension motivated by work in cognitive linguistics. For example, one framework that describes meaning construction in a way broad enough to encompass the variety of figurative phenomena previously discussed is conceptual integration, or blending theory, that describes regularities in the way that people combine information at various levels of abstraction (Fauconnier & Turner, 1998, 2002). The space structuring model attempts to characterize how speakers, given linguistic input in a particular context of use, exploit creative processes of meaning construction to form enriched meanings in context. Three important meaning construction processes in the space structuring model include partitioning information into mental spaces, establishing mappings between frames in different mental spaces, and integrating or blending information from different domains.

### Mental Spaces and Mapping

Mental space theory (Fauconnier, 1994) is a theory of referential structure in language motivated by the observation that people often need to refer to multiple, potentially conflicting construals of the same situation. For example, actors are frequently very different from the roles they play, and consequently different frames support one's understanding of an actor such as Orlando Bloom, and a character played by that actor, James Bond. To understand Sentence 10, one might partition the information into two mental spaces, a reality space where Orlando Bloom has the occupation of actor, and a movie space where James Bond has the occupation of secret agent (Coulson, 2005).

(10) Orlando Bloom is the new James Bond.

Mental space theory captures the fact that there is a nonarbitrary relationship between James Bond and Orlando Bloom via a mapping or correspondence between the element in movie space (Bond) and its counterpart in reality space (Bloom). Mappings in mental space theory can be based either on identity as in the mapping between Bond and Bloom, or on analogy as in the mapping between Bond's profession (spying) and Bloom's (acting). Mappings between cognitive models in different mental spaces are also important for metaphors such as that in Sentence 11.

(11) Merkel unveiled the details of the agreement.

The two mental spaces here are German politics (the target) and visual discovery (the source). In the visual discovery space there is an agent and a veiled face that respectively map onto Merkel and the agreement in the German politics space. The agent unveiling the face corresponds analogically to Merkel describing the details of the agreement. Coulson (2001) showed that the mapping in many metaphoric utterances is not simply between the source and the target spaces, but is mediated by a blended space, a mental space where some structure from each of the spaces is combined. These hybrid cognitive models, known as *blends*, are useful in explaining discrepancies between the way that shared cognitive models function in the source as compared to the target domain, as well as emergent properties of metaphoric expressions (Tourangeau & Rips, 1991).

## Conceptual Blending

Conceptual blending is at work in many of the examples discussed. For example, in cases of personification, as in the singing peanut studied by Nieuhaus and Van Berkum (in press), cultural models of being in love that pertain to a human behavior space are blended with an object (a peanut) from the peanut space. As a result, the singing peanut active in the blended space does not necessarily result in the readers changing their beliefs about peanuts in the peanut space. In the case of detective stories, one blends fictional characters such as Watson and Holmes from the story space with information in the 19th century England space. Moreover, in the fictive motion in Sentence 4, readers blend the predicate *runs* from the motion space with the blackboard in the reality space to impose a dynamic conceptualization on it (for further analysis, see Coulson & Oakley, 2005; Hutchins, 2005; Sinha, 2005).

Conceptual integration theory suggests that all language comprehension involves the construction of multiple cognitive models and the establishment of mappings based on analogy and identity (Coulson, 2001; Fauconnier & Turner, 1998, 2002). One upshot of the theory, then, is to undermine traditional distinctions between literal and nonliteral meaning. However, unlike many theories of metaphor comprehension that seek to reduce metaphor comprehension to word sense disambiguation, conceptual integration theory undermines the literal–nonliteral dichotomy by highlighting the import of imaginative processes of meaning construction in the comprehension of all language. The space structuring model is an attempt to capture the commonalities in literal and nonliteral language comprehension without ignoring the dynamic and context sensitive way that people construct meaning.

## Metaphor Comprehension

One prediction of the space structuring model is that words can evoke radically different information depending on the conceptual structure that has been evoked by the prior context. In a simple test of this prediction, Coulson & Matlock (2001) gave participants the same words used in different sorts of contexts and asked them to describe features of an underlined word. In the first part of the study, words were presented in the null context. For example, participants were given the word *anchor* and asked to list two to three features of an anchor. In the second part of the study words were presented in three sorts of sentence contexts. Target words could appear in their literal sense, as in Sentence 12a; in their metaphoric sense, as in Sentence 12b; or in an in-between condition called literal mapping, as in Sentence 12c.

(12a) Last time he went sailing he forgot about the anchor.
(12b) Amidst all the trappings of success his wife was his anchor.
(12c) We were able to use a barbell for an anchor.

Literal mapping stimuli employed fully literal uses of words in ways that were hypothesized to include some of the same conceptual operations as in metaphor comprehension. These sentences described cases where one object was substituted for another, one object was mistaken for another, or one object was used to represent another. Literal mapping sentences all employed contexts that required the comprehender to set up mappings between the two objects in question (in Sentence 12c, for example, between the barbell and the anchor), and the domains where they occur (a gym vs. a boat).

We found that approximately 60% of the features listed in each sentential context were also listed in the null context, indicating some degree of constancy in the conceptual structure available for meaning construction. However, there was also evidence for context sensitivity, as a large percentage of the features (ranging from 40–46%) for words generated in sentence contexts were unique to the particular sentence in which the word appeared. Statistical measures of semantic similarity (using latent semantic analysis) suggested null context feature sets were most similar to words in the literal contexts and least similar to the metaphorical contexts; literal mapping contexts fell somewhere in between. Presumably, a large part of the challenge of figurative language comprehension is the activation of conceptual structure that is not conventionally associated with a particular word, as well as establishing the relationship between aspects of previously unrelated concepts.

Consequently, Coulson and Van Petten (2002) hypothesized that the final words in Sentences 12a–12c would fall on a continuum of processing difficulty, with 12a at one end, 12b at the other, and 12c falling somewhere in the middle. This prediction was tested by comparing ERPs elicited by words in sentence contexts like those in 12a–12c, in which the same final word appeared in three different sentence contexts that differed in figurativity. In addition to being matched for lexical factors (because each word served as its own control), the cloze probability (predictability) of sentence final words was equated across the three sentence types. Differences in the ERPs would, thus, be related to integrating the sentence final word into the preceding sentence context.

Consistent with the predictions of conceptual blending theory, Coulson and Van Petten (2002) observed that ERPs in all three conditions were qualitatively similar, displaying similar waveshape and topography, for the first 500 ms after the onset of the sentence final word. This suggests that during the initial stages, processing was similar for all three sorts of contexts in engaging the same brain regions. Moreover, as predicted, N400 amplitude differed as a function of metaphoricity, with literal stimuli eliciting the least N400, literal mappings the next most, and metaphors eliciting the most N400, suggesting a concomitant gradient of processing difficulty related to the complexity of mapping and conceptual integration.

## CONCLUSION

Reviewing a number of studies of the brain's real-time processing of linguistic stimuli, I have pointed to results that highlight the flexible, creative character of meaning construction. I have suggested that traditional models of language comprehension as a decoding process involve an overattribution of the import of linguistic information and an overly narrow view of the role of background and contextual knowledge. Although linguistic information is indeed important, it neither contains nor conveys the meaning that is constructed by competent language users. Linguistic information is perhaps best viewed as prompting meaning construction processes such as the activation of frames, the establishment of mappings, and the integration or blending of information from different domains.

Neuroscience gives a picture of information processing as involving partitioning of sensory information into parallel streams, each computing different sorts of information, and each with its own hierarchical structure. The massively interconnected systems allow for information to be continuously mapped and remapped between intertwined processing streams. Similarly, the space structuring model portrays meaning construction as involving the partitioning of information into parallel streams, extensive mapping, and the integration of disparate information needed for adequate message-level comprehension. Although the establishment of abstract mappings in mental space theory is presumably not directly comparable to mapping in the visual system, perhaps computationally similar mechanisms of information regulation underlie the flexibility evident in both meaning construction and visual processing.

Consistent with a view of language as a tool for social interaction, the space structuring model suggests that people use language to activate information in memory so as to promote particular conceptualizations in their interlocutors. Cognitive neuroscience is useful here, too, in providing an alternative to conventional metaphors for memory, in which memory systems are construed as a series of holding cells, and memories as pieces of information moved from place to place. In neuroscience, however, memory is understood as experience driven changes in the brain that affect subsequent behavior (e.g., Fuster, 1997). The fundamental mechanism for memory formation is Hebbian learning, in which synaptic connections between neurons are strengthened as a result of temporally coincident firing ("Cells that fire together wire together"). Associations result in the formation of cell assemblies that serve as the functional units of memory, and retrieval is the transient activation of a cell assembly.

As memory is stored in overlapping and distributed networks of neurons, spatial metaphors for memory are not particularly apt. Information in memory does not exist in a particular place, but rather is inherent in the connections between the neurons in a cell assembly that facilitates their synchronous activity. The same neurons that mediate experience—perception and action in the world—also mediate memory for that experience. Further, due to the transient nature of cell assemblies, semantic memory representations are not constant, but change as a function of experience and context. The idea of language comprehension as a process of activating and linking information in memory follows naturally from neural processing mechanisms that are fundamentally constructive.

Hopefully, by now, my message to figurative language researchers is clear. They must not simply assume that folk models of language comprehension are empirically valid, and, perhaps more important, they must not let these models unwittingly influence the way they think. Cognitive neuroscience data reviewed argue against a deterministic, algorithmic coding and decoding model of meaning, and for a dynamic, context sensitive one. Moreover, this context sensitivity is not an incidental property, but rather a basic feature of the language architecture. Indeed, the pervasive nature of fictivity in language results because meaning construction processes are fundamentally imaginative. As such, figurative language research is central to the development of neurologically plausible models of meaning construction.

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