Psycholinguistics Electrified II (1994-2005).

Marta Kutas[1], Cyma K. Van Petten[2], Robert Kluender[3]

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1Departments of Cognitive Science and Neurosciences, University of California, San Diego, La Jolla, California
2Department of Psychology, University of Arizona, Tucson, Arizona
3Department of Linguistics, University of California, San Diego, La Jolla, California

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Correspondence to:
Dr. Marta Kutas
until Fall, 2006:
Department of Psychology
Hebrew University, Mt. Scopus
Jerusalem, Israel
mkutas@mscc.huji.ac.il
972-(0)2-588-0154

from September, 2006:
Department of Cognitive Science
University of California, San Diego
La Jolla, California 92093-0515
mkutas@ucsd.edu
858-534-7450

1. INTRODUCTION

Since the first edition of the *Handbook of Psycholinguistics* in 1994, investigations of language processing via electromagnetic recordings have proliferated beyond the possibility of coverage in any single chapter. Our aim here is to offer a sampling of the more seminal, influential, and controversial event-related brain potential (ERP) studies within the psychology of language, focusing on the last decade. Out of necessity, we restrict the review to studies of healthy young adults as this segment of the population is the typical baseline against which to assess results from infants, children, middle-aged and older adults, and individuals with neurological or psychiatric disorders. Length limitations also forced us to skip studies of speech perception and production, and those bearing on the automaticity of semantic processing, topics we plan to address in some future venue.

In 1994, there were only two dominant noninvasive techniques to offer insight about the functional organization of language from its brain bases: the behavior of brain-damaged patients (neuropsychology), and event-related brain potentials (ERPs). Positron emission tomographic and magnetoencephalographic (MEG) measures were just beginning to contribute to our understanding. Over the ensuing decade-plus, these have been joined by functional magnetic resonance imaging, transcranial magnetic stimulation, event related spectral changes in the electroencephalogram, and noninvasive optical imaging (see Gratton & Fabiani, 2001; Gratton, Fabiani, Elbert, & Rockstroh, 2003 for review of the last and newest technique). As outlined below, three of these methods are closely related in their neural and physical bases: ERPs, event-related frequency changes in the electroencephalogram, and magnetoencephalography. After that brief review of the neural bases of these methods, we devote a modicum of attention to the latter two methods and chiefly focus on ERP studies of language processing. The remainder of the review is then devoted to four major domains of language processing: visual word recognition, basic semantic processing, higher-level semantic processing, and syntax and morphology.

2. ELECTROMAGNETIC MEASURES OF BRAIN ACTIVITY

2.1 Neural activity and the electrotroencephalogram

Interactions between neurons are the essence of brain activity. These interactions consist of current flow – the movement of charged ions – across cell membranes, such that the direction and magnitude of current flow in one neuron depends on the neurons it communicates with. A recording electrode close to a neuron can detect one sort of rapid change in voltage (or potential) caused by rapid changes in current flow: the action potential that causes neurotransmitter release in the vicinity of another neuron. Placing an electrode close to a single neuron is too invasive for use in healthy humans. After neurotransmitter is released and bound by other neurons, the result is a change in current flow

of upcoming semantic, syntactic, and lexical information.

5.5 Nonliteral language

People use language in different ways for different purposes because it serves various communicative and social functions that go well beyond conveying facts. People don't always mean what they say, or say what they mean directly – and yet typically a reader/listener from the same culture as the speaker has no difficulty understanding that what s/he read or heard was a promise, a threat, a command, an indirect request or that a statement is dripping with irony, funny, or intended to be metaphorical. The psycholinguistic and linguistic literatures are rife with discussions about the extent to which there is a basic distinction between literal and nonliteral language representations and processes. Views span the range from those that argue that the dichotomy between literal and figurative thought or language is a psychological illusion and that a single set of processes is responsible for the processing of both, to the strong claim that figurative language is unusual and special, and as such engages different comprehension processes (Katz, Cacciari, Gibbs & Turner, 1998).

To date there are only a few electrophysiological investigations of nonliteral language processing, specifically of jokes and metaphors. One recurrent theme in these studies is whether the right hemisphere makes a special contribution to the comprehension of nonliteral language. This question has been of interest since early reports that one subtle communicative deficit in patients with damage to the right hemisphere is difficulty understanding nonliteral language (Brownell, Simpson, Bihrle, & Potter, 1990; but see Gagnon, Goulet, Giroux, & Joanette, 2003 for a recent claim that right- and left-hemisphere patients are more similar than different). None of the studies described below included neurological patients, relying instead on less direct means of assessing hemispheric asymmetry: examining the lateral distribution of scalp ERP effects, comparing right- and left-handed participants (on the hypothesis that left-handers have a somewhat more bilateral neural substrate for language, and visual half field presentations.

5.5.1 Jokes

Coulson and Kutas (2001) compared the processing of one-line jokes versus non-joke sentences, with final words matched on cloze probability. Their primary aim was to test a two-stage model of joke comprehension wherein an initial stage of "surprise" registration is followed by a stage of coherence re-establishment. They also were able to assess the psychological reality of *frame-shifting* – a process of activating a new frame from long-term memory in order to reinterpret information already in working memory (Coulson, 2001). Although not specific to jokes, frame shifting is necessary to re-establish coherence when encountering the punch word or line. As in many recent language studies, the specific pattern of results differed depending on contextual constraint (final word cloze above and below 40%) and whether or not individuals "got" the joke. Better joke comprehenders responded to jokes with larger late positivities (500-900 ms),

a sustained negativity over left frontal sites, and -- for those in constraining contexts -- a slightly larger N400 as well. By contrast, in the poorer joke comprehenders, the punch-words elicited an enhanced frontal negativity (300-700 ms). Coulson and Lovett (2004) likewise observed larger late positivities to jokes relative to cloze-equated straight endings, with a laterality influenced by participant handedness and gender. A frontal negativity was seen only in right handers, and a slightly enhanced N400 only in left handers with low verbal skills. The results were not simply explicable in terms of any two-stage theory. However, as the enhanced late positivity to jokes is not dissimilar to those reported for syntactic violations in nonhumorous sentences, it is worth considering the possible commonalities between the two in terms of sentence re-analysis, retrieval and integration of information in working memory, etc.

Coulson and Williams (2005) examined ERPs to similar materials when punch-words or straight endings were presented to one or the other hemifield to ensure that visual information reached one hemisphere slightly before the other. Jokes elicited larger N400s than straight endings only when the sentence-final words went into the right visual field (left hemisphere). With LVF presentation, both jokes and low-cloze straight endings elicited larger N400s than high-cloze non-joke endings, but did not differ from each another. A sustained frontal negativity and a late fronto-central positivity to jokes did not differ with visual field of presentation. Overall, the right hemisphere seems no more stymied by processing a joke as by any other unexpected noun, suggesting that it may be better able to use sentential context to facilitate processing and integration of a punch word. This conclusion is supported by the studies in Coulson and Wu (2005) showing that greater N400 reduction to single words in central vision relevant than irrelevant to an immediately preceding one-line joke as well as a greater reduction when such probe words were presented in the LVF than RVF (right hemisphere).

We can now re-consider whether joke processing differs from that of non-joke sentences. Certainly the data patterns indicate substantial overlap in processing, with the reading of both accompanied by modulations in N400 amplitude. At the same time, there appears to be a difference in the contributions of the two hemispheres to joke and non-joke processing; some aspect (unknown) of joke comprehension appears to be easier for the right hemisphere, as reflected in reduced N400s associated with lateralized presentation of either punch words or joke-relevant probe words following one-liners. Whether the ephemeral sustained negativity over left frontal sites also will prove to distinguish jokes from non-jokes remains to be seen. A similar uncertainty colors the specificity of the late positivities (frontal and/or parietal) that occasionally characterize the ERPs to jokes. What is most clear from these studies is the need to track more than just whether a sentence is a joke or not, including whether participants get it, and stable characteristics of participants such as verbal ability, handedness, familial handedness, and gender. Indeed, this is undoubtedly a valuable lesson for all language studies.

5.5.2 Metaphors

Most current processing models of metaphor comprehension assume that the same operations are involved in literal and metaphorical language comprehension, but that metaphorical language especially taxes certain operations (see Katz et al., 1998). Several sources of behavioral evidence indicate that metaphorical meanings are sometimes available with the same time course as literal meanings and may even compete with each other. Researchers have examined these issues with ERPs as equivalent reaction times don't necessarily translate into equivalent processing demands. Although the specific alternative to the standard view differs across the ERP papers published to date, no electrophysiological study has yet offered any strong evidence for a qualitative difference in the way literal and metaphorical language is processed. The final words of metaphors typically elicit slightly larger N400 amplitudes than equally unexpected (low cloze) words completing literal statements. This suggests that people invoke the same operations, but also do experience more difficulty integrating words with a metaphoric than literal context.

Pynte and colleagues initially established that final words of short metaphoric sentences elicited larger N400s than categorical statements, despite being matched on cloze probability Pynte, Besson, Robichon, & Poli, 1996). Subsequent experiments showed that the ease of processing metaphoric statement, like literal statements, could be modulated by prior context. When presented in isolation, relatively familiar and unfamiliar metaphors elicited equivalent ERPs (e.g., "Those fighters are LIONS." versus "Those apprentices are LIONS."). However, both sets of metaphors benefited from preceding context so that an unfamiliar metaphor with a useful context ("They are not cowardly. Those apprentices are LIONS.") elicited a smaller N400 than a familiar metaphor preceded by a irrelevant context ("They are not naïve. Those fighters are LIONS."), and similarly the familiar metaphors with a useful context were easier to process than unfamiliar metaphors with an irrelevant context. The metaphors-in-context were not compared to a literal condition to determine if the enhanced N400 observed for isolated metaphors disappeared with appropriate context. However, across the multiple experiments, there was no hint of distinct processing stages during metaphor comprehension.

While granting that none of the predictions of the standard view have stood the test of data, Tartter and colleagues raise the possibility that while processing a metaphorical expression comprehenders nonetheless do take note of the anomalous nature of the expression's literal meaning (Tartter, Gomes, Dubrovsky, Molholm, & Stewart, 2002). They suggest this realization may underlie the phenomenological sense of satisfaction experienced when confronting a metaphorical statement. They compared the ERPs to final words completing the same sentence frame either literally, metaphorically, or anomalously (e.g., "The flowers were watered by nature's RAIN / TEARS / LAUGHTER", respectively). Cloze probabilities were higher for the literal endings than the other two conditions (both near-zero). They argue that if context is used to construct a meaningful interpretation of a metaphorical expression without any accompanying appreciation that the expression's literal meaning is anomalous,

then a metaphorical but literally incongruous ending should not elicit an N400. This construal of the N400 as an anomaly detector is problematic given that words that fit but are less expected also elicit sizable N400s; semantic anomalies are neither necessary nor sufficient to elicit N400s. Tartter et al. obtained a three-way amplitude difference in the peak latency range of the N400: anomalous > metaphorical > literal, however, the ERPs to literal completions pulled away from the other two conditions earlier than the differentiation between metaphoric and anomalous completions. This pattern of results suggests (to us) that that semantically anomalous sentence endings were more difficult to process (as reflected in larger and longer N400 congruity effect) than the metaphorical endings which were in turn more difficult to fit with the prior context (as reflected in greater N400 activity) than the literal, congruent endings. The data pattern is also consistent with the view that metaphors are initially processed much the same as semantic anomalies although they are meaningfully resolved in a shorter duration. However, this latter conclusion is somewhat complicated by the difference in cloze probability and frequency between the literal and metaphoric completions.

A significant analytic and empirical step in this area was taken by Coulson and Van Petten (2002) who hypothesized that the same conceptual operations important for understanding metaphors are often also engaged during the comprehension of literal statements These include establishing mappings and recruiting background information, or, more specifically, looking for correspondences in attributes and relations between the target and source domains, setting up the mappings, aligning them, selecting some and suppressing others. By using sentences describing situations where one object was substituted, mistaken for, or used to represent another (the *literal mapping* condition, e.g., “He used cough syrup as an INTOXICANT.”), they created sentences requiring mappings between two objects and the domains in which they commonly occur, albeit with less effort than for a metaphor (e.g., “He knows that power is a strong INTOXICANT.”), but more than for a simple literal statement with fewer or no mappings (e.g., “He knows that whiskey is a strong INTOXICANT.”). ERPs elicited by sentence-final words showed graded N400 activity, with metaphor > literal mapping > literal, although the three conditions were matched in cloze probability. These data indicate that although literal and figurative language may engage qualitatively similar processes (in contrast to the now unpopular “standard view”), increasing the burdens on mapping and conceptual integration can make metaphors more difficult to process. .

Finally, Kazmerski and colleagues examined individual differences in metaphor comprehension, and found that both vocabulary and working memory capacity were important factors as individuals determined whether a metaphoric statement was literally untrue (as compared to false statements without metaphoric interpretations, e.g., “The beaver is a LUMBERJACK.” versus “The rumor was a LUMBERJACK.”). High IQ participants showed greater interference presumably because the figurative meaning was extracted without voluntary effort (Kazmerski, Blasko, & Dessalegn-Banchiamlack, 2003). Lower IQ participants had equivalent N400s for the metaphoric and anomalous statements,

suggesting that they had no additional trouble rejecting metaphorical sentences as untrue. Thus, although individuals with lower IQs clearly understood the metaphors in an offline task, the online evidence provided by the ERP seems to indicate that metaphorical processing is not always obligatory or automatic.

6. MORPHOSYNTACTIC PROCESSING AND RELATED COMPONENTS

This section surveys a number of issues concerning morphological and syntactic processing that have been addressed using ERPs: (1) the encapsulation and/or interaction of semantic and syntactic processes, (2) the influence of other, non-linguistic cognitive variables (such as working memory) on syntactic processing, and (3) the fractionation of syntactic processing into discrete stages. While the jury is still out on most of these issues, a body of evidence has begun to accumulate that allows us to reflect on just how much is known at this point. Invariably, predictions of Fodor's (1983) modularity hypothesis with regard to linguistic representations and processes provide much of the framework for this inquiry.

Before evaluating the evidence, however, it may be useful to invoke a caveat while it is relatively easy, via experimental manipulation of linguistic materials, to obtain differences in the polarity, latency, amplitude, and scalp distribution of brain responses, it is often difficult to ascertain exactly what such differences might reflect functionally.

6.1 Background

As Sections 4 and 5 make clear, the N400 has become well established as a brain index of semantic and pragmatic processing. More recently discovered components related to syntactic and morphological processing have both complicated this picture and raised questions about the extent to which the N400 should be considered an all-purpose index of semantic processing. As early as 1983, Kutas and Hillyard demonstrated that while violations of semantic well-formedness reliably elicited an N400 (but see section 6.2.2), violations of morphosyntactic well-formedness elicited different ERP components. In addition to semantic violations, the study included number agreement discrepancies (e.g. '*she dig*'; '*a balloons*'), as well as both finite and non-finite verb forms in inappropriate sentence contexts ('*to stayed*', '*are consider*'). In contrast to the centro-parietal N400 between 300-500 ms elicited by semantic anomalies, the responses to all three morphosyntactic violations showed *fronto-central* negativities between 300-400 ms and marginally significant parietal *positivities* at 300 ms post onset of words immediately following the violations (Kutas & Hillyard 1983, Figure 4). Although the import of these differences was not entirely clear at the time, Kutas and Hillyard observed that the elicitation of N400s by semantic but not morphosyntactic anomalies pointed to potentially separate underlying neural processing systems.

This state of affairs has largely persisted to the present day: morphosyntactic anomalies of various sorts have typically been associated with