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ERPs and Domain Specificity: Beating a Straw Horse

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We discuss the import, validity and implications of the identity thesis: the idea that the P600 component of the scalp recorded event-related brain potential is identical with the P3b, a domain-general component elicited by improbable task-relevant events. We point to data reported in Coulson, King and Kutas (1998), as well as more recently published findings, which suggest that the P600 component is sensitive to domain-general factors of probability, salience and task relevance. Exploring the epistemological complexities of the issue, we suggest what the identity thesis does and does not imply about the existence of a modular parser.

INTRODUCTION

Imagine you have been lured into the laboratory of a mad scientist who attaches electrodes to your scalp and asks you to sit quietly while he records your electroencephalogram (EEG). In one condition, you are asked to guess whether the next stimulus is a tone or a flash of light; in the other, you are presented with the exact same stimuli but are told ahead of time which stimulus you are about to encounter. Can the squiggly trace of the EEG *possibly* reveal anything useful about how your brain responds to the randomly presented flashes and tones? In fact, averaging the EEG timelocked to the presentation of tones and flashes yields a predictable

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series of positive and negative peaks known as the event-related brain potential (ERP). In the 1960s, it was well-known that the amplitude and latency of these peaks, or "components", in the ERP could be correlated with sensory aspects of processing. What was not known was whether signals recorded from the scalp could accurately reflect cognitive aspects of processing, such as whether the presentation of a tone was informative (confirming or disconfirming the participant's guess) or uninformative (confirming what the participant already knew to be true).

However, in a seminal paper, Sutton, Braren, Zubin and John (1965) published a report of the results of an experiment much like the one described above: ERPs elicited by informative stimuli contained a positive-going wave with a peak latency of approximately 300 msec that the authors labelled the P3. Moreover, decreasing the probability of either the tone or the flash resulted in increased amplitude P3 for the improbable event. Unlike previously discovered components (such as the visual-specific N1), the P3 was not specific to a particular sensory modality, and seemed to be a manifestation of information processing in the cortex. The discovery of a neuroelectric index of cognitive processing set off a flurry of research into the properties of this ERP component.

Since the publication of Sutton and co-workers' (1965) initial paper, the P3 has been associated with cognitive activities such as decision making, target selection, sensory discrimination and match–mismatch processing (see Picton, 1992, for a review). Moreover, careful experimentation indicates that the P3 is not a unitary component, but can be broken down into at least three subcomponents known as the P3a, P3b and Slow Wave, each of which displays distinct scalp distributions and sensitivity to different independent variables. Of these, the most heavily investigated, and the one which we are most concerned with here, is the P3b: a broadly distributed positive-going component with a centroparietal maximum whose amplitude is sensitive to subjective aspects of stimuli such as task relevance, salience and probability. Elicitation of the P3b is thought by some to reflect the resolution of uncertainty and the task-relevant surprise value of a stimulus.

ERP research has since revealed a number of other endogenous components which index various aspects of sensory, motor, and cognitive processing. While is has been customary to mention only the polarity and latency when naming an ERP component, the modern understanding of a component implies electrical activity that displays a particular topography, or distribution, over the scalp. Moreover, because components are thought to be the manifestation of cognitive processing operations, the latency at which they peak can vary with the complexity of the operations required by different sorts of stimuli. These factors can even lead to the elicitation of two or more components whose time courses overlap to some degree,

requiring clever experimental designs to disentangle their differential sensitivities to independent variables.

Historically, ERP components have been used both as a topic of research (so-called "componentology"), in which investigators attempt to characterise the information processing operations that result in the elicitation of a component), and as a tool, in which investigators use one or more components in the ERP as multidimensional dependent measures of processing (Donchin, 1981). One area in which ERPs have proven particularly useful is in the study of language processing. Researchers in this area have identified a number of ERP components sensitive to linguistic variables, including the N400, various left anterior negativities (LANs), the lexical processing negativity (LPN) and the P600 (see Osterhout & Holcomb, 1995, for a review). In particular, the positive-going P600 has attracted the attention of sentence processing researchers because of its sensitivity to syntactic variables such as the grammaticality of a given sentence.

Because the promise of ERPs includes the possibility of treating an ERP component as a topic, and thus linking cognitive and neural processes, it is tempting to overinterpret the discovery of new ERP components. For example, one might be tempted to jump from the report of a syntax-sensitive ERP component such as the P600 to the existence of brain regions and processes that are domain-specific. Though appropriately sceptical in their speculation, some investigators have interpreted the differential sensitivity of the N400 and P600 to semantic and syntactic variables as indicative of discrete semantics- and syntax-specific brain regions (e.g. Neville et al., 1991). Furthermore, Osterhout, McKinnon, Bersick and Corey (1996) have argued that the P600 might be a language-specific brain response, and thus suggest the existence of language-specific brain processes.

A salient alternative to this latter possibility is something we refer to as the *identity thesis*: the thesis that the P600 is in fact a P3b elicited by the recognition of improbable linguistic events. Given certain similarities between the two components, many psychophysiologists have pondered the relationship between the P600 and the P3b. In fact, in recent years, at least three studies have been published about the validity of the identity thesis. One, by Osterhout et al. (1996), concludes that the identity thesis is false; another two, one by Coulson, King and Kutas (1998) and one by Gunter, Stowe and Mulder (1997), conclude that the two components are essentially similar.

In this reply to Osterhout and Hagoort (this issue), we discuss the import, validity and implications of the identity thesis, drawing on our earlier work, as well as a number of recently published findings. In the next section, we reiterate the data that motivated Coulson et al. (1998) to claim

that the P600 brain response to syntactic violations is a P3b elicited by the rare event of ungrammaticality. We then dismiss many of the specific claims made by Osterhout and Hagoort (this issue). Finally, we consider what the identity thesis does and does not imply about the nature of language processing.

THE FACTS

The identity of the P600 and the P3b is suggested both by concrete similarities in their "appearance", and by abstract similarities in their functional characterisation. Both are broadly distributed positive-going components with a centroparietal maximum. While the literature suggests subtle differences between them, these discrepancies are probably attributable to overlap with other components and differential latency variability across single trials. Moreover, there is a certain commonality in their eliciting conditions. The P3b is associated both with the categorisation of task-relevant events and the perception of unexpected events. The P600 is associated with sentences which are ungrammatical, or which promote a dispreferred syntactic analysis. Thus, for ungrammatical sentences, the P600 might be a P3b elicited because participants spontaneously categorise sentences as ungrammatical; for dispreferred syntactic analysis, perhaps the P600 is a P3b elicited as participants terminate misanalysis. In fact, language processing requires the reader or listener to categorise stimuli at multiple levels in ways, which might result in a P3b.

To test the identity thesis, Coulson et al. (1998) recorded participants' ERPs as they read two sorts of English sentences: verb agreement sentences, as in (1a) and (1b), and pronoun case sentences, as in (2a) and (2b).

1a. Every Monday he mows the lawn.
1b. Every Monday he *mow the lawn.
2a. Ray fell down and skinned his knee.
2b. Ray fell down and skinned *he knee.

Moreover, because a chief characteristic of the P3b is sensitivity to probability manipulations, Coulson et al. (1998) also varied the proportion of grammatical to ungrammatical sentences across different blocks of experimental sessions. During one half of the experiment, grammatical sentences were the norm, comprising 80% of grammatical stimuli. During the other half of the experiment, ungrammatical sentences were the norm,

comprising 80% of the stimuli. If the identity thesis is correct—and the P600 is a P3b triggered by the categorisation of sentences as ungrammatical—then varying the relative proportion of grammatical to ungrammatical sentences should modulate P3b amplitude to items most relevant to the sentence's ungrammaticality. Thus while elicitation of a probability effect does not *prove* the identity thesis, the absence of a main effect of probability (or a probability effect which was obviously not a P3b) would serve to falsify it.

However, Coulson et al. reported main effects of both the probability and the grammaticality manipulations. Consistent with earlier reports in the literature (see Kutas et al., in press, for a review), words which rendered a sentence ungrammatical elicited more positive ERPs 500–900 msec post-word onset than their grammatical counterparts. Moreover, regardless of whether the improbable events were grammatical or ungrammatical, improbable sentence types elicited an enhanced positivity to the same class of words in the same time window as the grammaticality effect. In view of the ERP literature on syntactic anomalies and task-relevant oddballs, Coulson et al. surmised that the grammaticality effect was a P600 and the probability effect was a P3b. Given elicitation of both effects, the identity thesis could have been falsified in two ways.

First, if these two effects were generated by different brain regions, we might expect their scalp distributions—that is, the relative amplitude of the late positivity at different sites on the scalp—to differ as well. However, consistent with reports in the literature of broadly characterised similarities in their topography, the distribution of the two effects was statistically indistinguishable. More important for the validity of the identity thesis, however, is the additivity or non-additivity of the two brain responses. Due to physical properties of the ERP signal, distinct neural generators have additive effects on its amplitude. Consequently, if the generators of our two effects were different, we would have expected to see additive effects of grammaticality and probability. In contrast, the identity thesis predicts non-additive effects of a particular character—with a much larger effect of probability on the already salient ungrammatical stimuli than on their grammatical counterparts.

The data reported in Coulson et al. (1998) argue strongly for the identity thesis. Experimental manipulation of both grammaticality and probability elicited late positivities with very similar scalp distributions. Moreover, we also observed an interaction of the predicted character. While the probability manipulation affected ERPs to both grammatical and ungrammatical events, the effect was much larger in ungrammatical stimuli. Furthermore, just as the salience of a stimulus is known to modulate P3b amplitude, Coulson et al. observed a larger positivity for the more salient pronoun case violations than for the verb agreement errors.

THE RHETORIC

In this section, we address some of the specific concerns raised by Osterhout and Hagoort in their reply to Coulson et al. (1998).

Import of the Identity Thesis

Osterhout and Hagoort begin their reply by questioning the import of the identity thesis. Noting that the P3 is not a monolithic component, they argue that the identity thesis is not worth testing. Ironically, they proceed to describe the results of a series of experiments reported by Osterhout and colleagues in which they tested "the possibility that the syntactic positive shift is a member of the P300 family of late positive components elicited by a wide variety of (linguistic and nonlinguistic) events" (Osterhout et al., 1996, p. 508). While we have more than a little sympathy for the point raised by Osterhout and Hagoort about the complexity of the neural events that underlie the ERP signal, we nonetheless maintain that the identity thesis is a worthy topic of investigation.

In fact, ERP researchers' use of the term "component"—an ingredient, or more technically any one of the terms in a vector sum—reflects the understanding that scalp-recorded ERPs represent activity in multiple brain sites. Moreover, while some researchers identify the notion of component with the activity produced in a particular set of neural generators, others invoke the notion of shared function (Donchin & Coles, 1988). For instance, although slightly different neuronal populations are active in the generation of the visual and auditory N2, many investigators consider both to be the manifestation of the same functional process (Ritter & Ruchkin, 1992). Besides similarities in their functional characterisation, there is a physiological motivation for this reasoning. As spatially contiguous cortical areas frequently occupy the same level of the cortical processing hierarchy, we might expect similar processes to be manifested in similarly modulated ERP components with only subtly different scalp distributions.

Because ERP components reflect neural activity in multiple brain locations, ascertaining their functional significance is all the more important. We echo Gunter et al. (1997) in noting that the sensitivity of the P600 to syntactic variables is not in question: the P600 is often elicited by syntactic anomalies and sentences which contain syntactic ambiguities. In exploring the relationship between the P600 and the P3b, the issue is whether P600 modulation by syntactic variables is related to domain-general processes such as context updating. Gunter et al. note that a positive answer only broadens the number of hypotheses that can be tested with the P600.

Moreover, given the vast amount of data collected on the eliciting conditions for the P3b, the knowledge that the P600 is a member of the P3 family can help greatly in the interpretation and design of experiments. For example, in our experiment, the same exact stimuli elicited a much larger (un)grammaticality effect when they occurred in the context of 80% grammatical blocks than in 80% ungrammatical blocks. A researcher unaware of the probability sensitivity of the P600/P3b might misinterpret differences in results across experiments which had been inadvertently induced by differences in the number or character of filler items. On the other hand, a savvy researcher might purposely exploit this factor to increase the power of his or her design.

Validity of the Identity Thesis

Design Issues

Osterhout and Hagoort (this issue) suggest that the design of the experiment reported in Coulson et al. (1998) is not appropriate for addressing the identity thesis. They argue that, to assess the relationship between these two components, it is necessary to compare ERPs elicited by syntactic and non-syntactic anomalies. Indeed, to address the *domain specificity* of the P600 it is necessary to compare ERPs elicited by syntactic and non-syntactic anomalies. However, Coulson et al. did not aim to test the domain specificity of the P600 *per se*, but rather its relationship to the P300 family of components. Given our far more modest goals, the design of the experiment reported in Coulson et al. (1998) is perfectly appropriate for testing the relationship between two ERP components.

Osterhout and Hagoort prefer to point to the results of the study by Osterhout et al. (1996), in which they compared the brain response to subject–verb agreement violations with that elicited by presenting critical words in capital letters. Their conclusion that the identity thesis is false rests mainly on the claim that the brain responses to syntactic and non-syntactic anomalies were additive (Osterhout et al., 1996). Osterhout and Hagoort write, "the upper-case and agreement anomalies had additive effects when both were presented simultaneously, and this additivity approximated a linear summation when the presumably non-additive effects of task relevance were taken into account".

But what Osterhout and Hagoort gloss as taking task relevance "into account" was to compare different ERP effects elicited in two different experiments with two different groups of participants. Because the overall amplitude of ERPs varies from individual to individual, such a comparison is of questionable value. Moreover, because physical features are typically easier to process than grammatical ones, a direct comparison of the brain

response to low-level physical features and higher-order grammatical processes is inappropriate (Gunter et al., 1997). In contrast, Patel et al. (in press) address the question of domain specificity by comparing the brain response to grammatical anomalies with anomalies in a non-linguistic domain of roughly comparable complexity—that is, music.

Although music is not linguistic, it is a complex, rule-governed phenomenon. Just as speakers can detect anomalies in sentences they have never heard before, listeners can detect out-of-key notes in novel musical sequences. Comparing ERPs elicited by violations in easy, difficult and very difficult sentences with those elicited by violations in easy, difficult and very difficult musical sequences, Patel et al. (in press) found a similarity distributed positivity was elicited by both sorts of anomalies. Moreover, both positivities were similarly modulated by the difficulty manipulation: the most difficult sequences and sentences elicited the most pronounced positivities.

Of course, asking whether or not two components are the same, or similar, raises the question of similarity with respect to what dimension. To be sure, for us, meaningful similarity involves the identity of the underlying neural generators. But, perhaps more importantly, it makes recourse to being similarly modulated by experimental variables. Similarity at this level suggests comparable computational processes are occurring in association with the performance of the two tasks. A good test of the identity thesis would, then, involve the prediction that the P600 and the P3b are modulated by the same variables. In the case of the P3b, these variables include subjective probability, salience and task relevance. Below we point to evidence that indicates the P600's sensitivity to these variables.

Superficial Resemblance and the Probability-600

In an attempt to explain away Coulson and co-workers' (1998) finding of a similar topography for the grammaticality and probability effects, Osterhout and Hagoort make two different arguments. One argument assumes that the effects had distinct neural generators, while the second admits they did not. We refer to the former argument as "Superficial Resemblance" and to the latter as "Probability-600". In the Superficial Resemblance argument, Osterhout and Hagoort note that, while different scalp distributions always signal differences in the underlying neural generators, the converse inference does not obtain. It is indeed possible for different neuronal populations to generate ERP effects which look quite similar at the scalp (Nuñez, 1981). Thus the fact that Coulson et al. found the predicted similarities in the topography of the two ERP effects is not particularly compelling.

Probability. However, as argued above, the identity thesis makes a number of predictions besides the null effect of scalp distribution. For example, it predicts that varying the proportion of grammatical to ungrammatical sentences will yield a probability effect that matches the characteristics of a P3b, including its positive polarity, its centroparietal distribution and an amplitude inversely proportional to subjective probability. We note in passing that Osterhout and colleagues (1996) interpret their own failure to find a probability effect as evidence against the identity thesis. But most importantly, perhaps, the identity thesis predicts the brain response to grammaticality and probability will be non-additive, as well as the particular character of the interaction.

This brings us to Osterhout and Hagoort's Probability-600 argument, in which they admit the probability-sensitivity of the P600, but question its import. Because the P3 is not the only ERP component sensitive to probability, probability-sensitivity is not a sufficient condition for establishing the identity thesis. Thus the Probability-600 argument stipulates that the grammaticality and the probability effects might result from activity in the same neural generators. On such a construal, the results reported by Coulson et al. (1998) reflect the probability-sensitivity of the P600, rather than the P3b's sensitivity to grammaticality. While we find this line of reasoning entirely plausible, we note that the character of the probability-sensitivity displayed by the P600 is remarkably similar to that of the P3b.

Salience. Besides probability, the P600 has also been shown to be sensitive to a number of other variables known to modulate the P3b. For example, given two events of equal probability, P3b amplitude is larger for the more salient event (e.g. Johnston & Holcomb, 1980). Thus the observation of Coulson et al. that the more salient pronoun case errors elicited a larger positivity than verb agreement errors suggests a further similarity between the P600 and the P3b. Osterhout and Hagoort object to this conclusion, noting that Coulson et al. did not provide independent behavioural evidence that the pronoun case violations were more salient than violations of subject–verb agreement.

Because we assumed native English speakers would share our intuition that the pronoun case violation is more salient (cf. examples 1b and 2b), we did not include these data in the original report. However, during post-experiment debriefing, participants were asked to recall examples of anomalous sentences, while all 16 produced examples of pronoun case violations, only 9 produced examples of subject–verb agreement violations. Of course, when shown examples of stimuli, recognition of both types of violations was unanimous. Similarly, Mecklinger, Schriefers, Steinhauer

and Friederici (1995) reported that the salience of a syntactic violation can affect both the latency and amplitude of the P600.

Osterhout and Hagoort also point to evidence which they claim suggests P600 amplitude is independent of salience. Hagoort, Brown and van Groothusen (1993), for example, found a much larger P600 for phrase structure violations than for equally salient violations of subject–verb agreement. However, Osterhout and Hagoort defined the salience of these violations by the number of participants (99 *vs* 97%) who judged their examples to be ungrammatical. Unfortunately, salience is not determined by the mere possibility of being classified as a violation. Embezzling a thousand dollars and embezzling a million are both violations. However, the latter is more salient.

Task Relevance. Task relevance is another variable known to affect the amplitude of the P3b, and recent evidence suggests that this factor also affects the amplitude of the P600. In a between-participants comparison, the P600 elicited by syntactic anomalies was larger in participants explicitly instructed to make grammaticality judgements than in participants whose tasks was reading for comprehension (Osterhout et al., 1996). However, because participants in a reading experiment are likely to spontaneously consider grammaticality a relevant factor, a better test of whether P600 amplitude is modulated by task relevance would involve comparing a task that directs attention towards grammaticality with one that directs participants' attention away from it (Coulson et al., 1998). To this end, Gunter, Friederici and Mecklinger (1996) compared the P600 elicited by syntactic anomalies when the task involved "shallow" judgements about type font (i.e. upper- *vs* lower-case letters) versus ERPs elicited when those same participants were making grammaticality judgements. The P600 elicited by ungrammatical events was markedly reduced when participants' attention was directed away from the grammaticality of the stimuli.

Attractor Landscapes and Domain Specificity

Osterhout and Hagoort (this issue) claim that the relationship between the P600/SPS and the P3 has received an undue amount of attention. Rhetorically asking, "What explains the tendency to debate these issues for the P600/SPS but not or less so for other ERP responses?", they suggest the P3's place in history makes it a sort of "gravitational attractor" for researchers in the field. In contrast, we note that questions about the relationship between different ERP components invariably arise in cognitive electrophysiology, both among those interested in language and among those interested in other cognitive processes.

In fact, the propensity to assimilate newly discovered components with more familiar ERP effects has characterised cognitive electrophysiology from the very beginning. For example, less than 5 years after the discovery of the P3 (Sutton et al., 1965) and the CNV (Walter et al., 1964), a slowly rising negative wave thought to reflect participants' growing anticipation of upcoming events, a controversy ensued about whether the P3 was merely the resolution of the CNV (Cohen, 1969; Donchin & Smith, 1970; Näätänen, 1970). Today, it is accepted by most researchers that the P3 and the CNV are distinct components elicited in many of the same experimental situations.

Moreover, the discovery of the first language-relevant component, the N400 (Kutas & Hillyard, 1980), prompted a number of researchers to investigate its relationship to the N2 (Deacon, Breton, Ritter, & Vaughan, 1991; Polich, 1985). One of the most interesting threads in N400 research has concerned whether the processes it indexes are specific to language. For instance, Besson and Macar (1987) tested if the N400 is elicited by violations of linguistic and non-linguistic sequences, including sentences, geometric patterns of increasing or decreasing size, musical scales and well-known melodies. Interestingly, anomalies in sentences elicited the N400, while both musical and geometric anomalies elicited late positivities. Furthermore, to assess the relationship between semantic aspects of object recognition and language processing, Ganis, Kutas and Sereno (1996) compared ERPs elicited by words and pictures. They found that, while pictures elicited an N4-like component, its scalp distribution differed slightly from the verbal N400.

Perhaps more closely related to the issue at hand is the debate about the existence of ERP components that differentiate between the processing of *open-class* words that primarily provide semantic information, and *closed-class* words that provide important grammatical information. For example, Neville, Mills and Lawson (1992) noted that open-class but not closed-class words elicit the N400; moreover, they reported that closed-class words elicit two components, the N280 and N400–700, not elicited by open-class words. Pointing to convergent evidence from the neuropsychological literature, Neville and colleagues argued that these differential ERP effects suggest that different neural systems mediate semantic and grammatical aspects of language processing.

However, other researchers have argued that differences in ERPs to open- and closed-class words can be attributed to more general factors that tend to be correlated with class membership. For example, several groups have suggested that the apparent absence of the N400 in closed-class items reflects their higher frequency and greater predictability (Garnsey, 1985; Kluender & Kutas, 1993; Van Petten & Kutas, 1991). Moreover, at least two groups have demonstrated that the N280 is an instance of a component

King and Kutas (1998) have referred to as the LPN (lexical processing negativity), as it is elicited by all visually presented words, and as the FSN (frequency-sensitive negativity), because of its sensitivity to word frequency. Using regression analyses on ERPs elicited by both open- and closed-class words, Osterhout, Bersick and McKinnon (1997) have demonstrated that the latency of the LPN is highly correlated with word length and inverse log frequency. King and Kutas argue that the LPN's sensitivity to the very same variables that predict eye movement latencies reflects plastic changes in the visual system resulting from many years of reading practice.

Similarly, the suggestion of Neville et al. (1992) that the N400–700 might index parsing operations triggered by closed-class words has been countered by an alternative suggestion that the N400–700 is "just" a CNV (Van Petten & Kutas, 1991). Noting that the amplitude of the N400–700 increases over the course of congruous sentences, Van Petten (1995) suggested it is a CNV potential whose amplitude reflects readers' anticipation of he upcoming word. Because they are short, frequent and tend to signal upcoming information (e.g. the ___?), closed-class words might be expected to elicit a rise in the CNV. In summary, disputes about the language- or syntax-specificity of language-relevant ERP effects are more the rule than the exception. The current dispute about the P600/SPS is hardly unique in this respect. We suspect that the real "gravitational attractor" is the issue of domain specificity. In the next section, we turn to this issue.

Components and Cognition

Syntax versus Semantics. As noted in the Introduction, one of the most exciting facets of ERP language research is the possibility of finding measures which are differentially sensitive to various aspects of linguistic representation. For example, Osterhout and Hagoort suggest that N400 and P600—two components that everyone agrees are distinct brain responses that are sensitive to different linguistic variables—might be used to disentangle the representational locus of parsing difficulty into discrete semantic and syntactic components. While we are optimistic about the possibility of exploiting the differential sensitivity of the many language-relevant ERP components, we remain sceptical that physiological measures such as ERP components will map transparently onto existing categories of linguistic representation.

We agree fully with Osterhout and Hagoort that existing data suggest the P600 is more sensitive than the N400 to grammatical manipulations, and that the N400 is more sensitive than the P600 to semantic–pragmatic manipulations. However, the data do *not* support the contention that the

P600 responds *specifically* to syntactic manipulations, as positivities are sometimes observed in association with violations which most people would consider semantic (Gunter et al., 1997; Münte, Schuchardt, & Heinze, 1993). Conversely, the N400 is often modulated by violations typically considered grammatical (e.g. Ainsworth-Darnell, Shulman, & Boland, 1998). Recently, Hopf, Bayer, Bader and Meng (1998) reported that the N400, but not the P600, was elicited by the presentation of a syntactic ambiguity at the level of case. By exploiting various aspects of the German case marking system, these investigators were able to construct stimuli such that all sentence types employed were both acceptable and identical until the final word; also, the dispreferred analysis was perfectly plausible.

How does the P600 Compare to Other Language-relevant Components? Osterhout and Hagoort argue that the relationship between the P600 and natural language processing (NLP) does not differ from that between NLP and other language-relevant ERP components. At a certain level, we are in full agreement. After all, ERP effects recorded at the scalp are only a *manifestation* of the cognitive operations with which they are associated, and need not be considered identical with them. However, it is also important to consider the relationship between ERP components and the sorts of variables which modulate them. Moreover, at this level, P600 amplitude has been shown to be modulated by domain-general variables such as probability and task relevance, as well as linguistic variables such as grammaticality.

For example, the P600 is less representationally specific than the negatives (or LAN) often elicited by the same stimuli. In ERPs recorded from participants reading naturalistic German texts, Münte, Heinze, Matzke, Wieringa, and Johannes (1998) reported that late positivities were elicited by three types of anomalies, including words which were misspelled, semantically odd and incorrectly marked for case. Furthermore, although the positivity was elicited regardless of the violation type, the preceding negativities seemed to be more sensitive to the nature of the violation. Case violations elicited a frontally distributed negativity, while orthographic and semantic violations elicited a negativity with a more central distribution. Also, the P600 is sensitive to non-syntactic variables, whereas LANs elicited the same paradigm are not.

The existing data suggest that, while the P600 is sensitive to probability, LANs are not (Coulson et al., 1998; Gunter et al., 1997). Similarly, while the P600 is sensitive to semantic congruency, thus far LANs are not (Gunter et al., 1997). Münte, Matzke and Johannes (1997) present data suggesting that while the P600 is sensitive to the "amount" of semantic content, LANs are not. In their experiment, ERPs elicited by subject–verb

errors in simple sentences composed of real German words were contrasted with sentences in which nouns and verbs had been replaced by German pseudo-words. Münte et al. found that while violations in both conditions elicited LANs, violations in the pseudo-words failed to elicit a subsequent positivity. The absence of a positivity in the pseudo-word condition argues against the hypothesis that the P600 serves as a direct index of morphosyntactic processing. Taken together, these findings point to a rather general role for the P600 as indexing a reanalysis process in which information gets recruited from many different sorts of representations.

CONCLUSIONS

Thus far, our response to Osterhout and Hagoort has primarily focused on interpretation of the data rather than evaluation of specific psycholinguistic models. While more or less in the spirit of the original paper (Coulson et al., 1998), it might be construed as an attempt to avoid an important question raised by Osterhout and Hagoort's reply, namely: "What can the P600 tell us about the modularity of the parser?".

In fact, depending on how one understands the buzzwords in this question, the answer might range from "very little" to "too much". At the low end of the scale (i.e. very little), it may be that while P600 elicitation is sometimes indicative of the status of parsing operations, it is not perfectly coupled to the output of the parser. In this case, the P600 is less informative about the modularity of the parser than some would like. On the other hand, if there is any reliable coupling (possibly for particular kinds of parsing operations), the existence of the P600 suggests a categorical sensitivity to well-formedness that is influenced by putatively non-grammatical variables such as semantic congruity. Similarly, if one believes that a modular parser would be insensitive to probabilistic effects, and that the P600 is a direct index of parsing, the results of Coulson et al. (1998) undermine a modular view.

What the Identity Thesis *Does* and *Does not* Imply

Identity can be a powerful tool to the extent that it suggests new avenues of research based on more established findings, or helps us to explore the similarities and differences between the processing of language and other hierarchically structured sequences such as music. The validity of the identity thesis thus suggests that the P600 might be generated by the same neuronal populations as those which generate the P3b in oddball detection, stimulus categorisation, decision making and other tasks associated with

this latter component. What the identity thesis does not suggest, however, is that parsing reduces to oddball detection. Just as when children "acquire" language they learn more than how to classify strings into those which are grammatical and those which are not, detection without construction is no model of language processing.

Moreover, we believe that Osterhout and Hagoort would do well to consider the possibility that some brain processes invoked for linguistic processing are also invoked for other cognitive processes. Before the P600 had ever been detected, decades of work had been done that situated the P3b in processes of categorisation, decision making and context updating which might be germane to parsing. For example, one might strive to precisely characterise the specific operations in linguistic and non-linguistic processing that recruit the same neural machinery. Perhaps testing these sorts of hypotheses would lead to further specified theories about the representations and processes that underlie linguistic and non-linguistic behaviour alike.

In fact, a number of ERP language researchers have fruitfully considered the question of how eliciting conditions for the P600 might be related to extant hypotheses about the functional significance of the P3b. For example, several groups have suggested that the late positivity indexes a general recomputation process prompted by various sorts of anomalies (Gunter et al., 1997; Münte et al., 1997). Similarly, Patel et al. (in press) suggest the P600 reflects knowledge-based structural integration. Furthermore, Rösler et al. (1998) note that the functional characterisations of the P300 are congruent with the computational demands necessary to deal with an unexpected syntactic event—even if the event does not render the sentence ungrammatical. To deal with such events, the reader must recognise the unexpected event, suppress the incorrect interpretation, and reanalyse the meaning of the sentence. Far from assigning syntax to an underspecified account of context updating, these researchers have undertaken innovative integration of ideas from physiology, psychology and linguistics.

In placing the emphasis on the difference between the brain response to linguistic and non-linguistic anomalies, Osterhout and Hagoort seem to ignore the most striking aspect of our findings. Recognising linguistic anomalies as anomalies requires (1) at least a rudimentary competence with the language in question, and (2) that the stimuli be processed as language. Just as the colour-blind participant will not generate a P3b to the odd red square in a succession of green squares, a monolingual speaker of Chinese will not generate a P600 to violations of English grammar, even though her P3b to sensory oddballs might be intact. The possibility of such dissociations reinforces our contention that the P600—much like self-paced reading times, naming latencies and many other psycholinguistic

measures—is not a direct manifestation of the parser. Nonetheless, the finding that the recognition of certain sorts of syntactic oddities elicits a P3b only reinforces its value to the psycholinguist (Coulson et al., 1998; Gunter et al., 1997).

On Parsing

Osterhout and Hagoort argue that the identity thesis has no bearing on the existence of a modular parser. We concur. However, we cannot agree with the following gross misconstrual of our position: "What Coulson et al. presumably mean is that there is no parsing at all."

In fact, our research includes investigation of the processing of simple transitive clauses (King & Kutas, 1996), relative clauses (King & Just, 1991; King & Kutas, 1995; Mueller, King, & Kutas, 1997) and complex non-local constructions such as X-let alone-Y (Coulson & Van Petten, 1998). In pointing to sign-based frameworks such as Cognitive Grammar (Langacker, 1987) and Construction Grammar (Fillmore, Kay, & O'Connor, 1988), we suggest that there is no discrete boundary between lexical and syntactic representations. Rather, lexical items, idioms and grammatical constructions all pair phonological form with meaning, and are all represented in the lexicon (Goldberg, 1995). While lexical items are simple constructions that pair specific phonological forms with their meanings, constructions for wh-questions and relative clauses, for example, are less specified for phonological form and often have semantic and pragmatic properties which are quite abstract (Kay, 1995). In such a framework, parsing involves activating all relevant constructions and integrating their meanings.

The tenability of such a position is supported by the rise of unification-based grammars in linguistic theory (e.g. Bresnan, 1982; Pollard & Sag, 1994; Sag et al., 1986), as well as by recent advances in computational linguistics which suggest that lexicalising the grammar can offer distinct advantages over more traditional parsers (Brill & Mooney, 1997). In psycholinguistics, a unified theory of lexical and grammatical processing is suggested by a wide variety of data from domains including child language development, the breakdown of language in neurological disorders, and on-line language processing in normal adults (Bates & Goodman, 1997). Moreover, in cognitive science, Jurafsky (1996) has demonstrated how a probabilistic parsing algorithm premised on Construction Grammar can provide a unified explanation of human data on lexical and syntactic disambiguation. By integrating phonological, syntactic and semantic information, Jurafsky's algorithm uses Bayesian techniques to determine the best parse.

What's in a Name?

We suspect that Osterhout and Hagoort agree with us more than they disagree with us. We all agree that, though sensitive to grammatical variables, the P600 is not a direct manifestation of the parser. Consequently, we all agree the identity thesis is, in fact, orthogonal to the issue of whether there is a modular parser. And, perhaps most importantly, we are all committed to the value of language relevant ERPs as a research tool in psycholinguistics.

It would seem, then, that the main point of disagreement concerns the extent to which the brain regions active in the generation of the P600 are dedicated to language processing. While Osterhout and Hagoort emphasise data which suggest language processing regions might be partially distinct from regions invoked in other sorts of cognitive processing, we have emphasised similarities in the functional characterisation of the brain response during linguistic and domain-general processing. In summary, we suggest that, regardless of what one wants to call the late positivity so often associated with the processing of improbable grammatical events—be it P600, P3b or even "Ethel"—we hope to have demonstrated its sensitivity to the factors of probability, salience and task relevance.

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