

On the on-line study of language comprehension

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Language has been studied in many ways. It has been examined as art, as a basis of philosophical investigations, and as a way of gaining insight into the human mind.

During the past fifty years, practitioners of various scientific disciplines have developed objective ways of studying language. Linguists try to understand language through the construction of theories of abstract linguistic knowledge. Psycholinguists try to understand how language users engage this knowledge in comprehension and production. Neuroscientists have been digging into the biological substrate of language. The present book provides a glimpse of how research done by linguists, psycholinguists, and neuroscientists can be brought to bear on a fundamentally psychological question, how language is comprehended in real time.

The topic of real-time comprehension of language has held centre stage through most of the history of psycholinguistics. This is because psycholinguists have tried to develop theories of how language is comprehended that spell out the cognitive processes taking place when language is being understood. Such an “information processing” model takes the form of claims about how mental representations are created, transformed, and stored, about what types of information are used in performing these operations, and about the architecture of the system that supports the proposed processes. A minimal (but difficult!) criterion for an adequate process model is whether it can create appropriate final outcomes, i.e., whether it can create representations that adequately capture what readers and listeners understand sentences and texts to mean. Given that this criterion has been met, even crudely, a second very challenging criterion can be

addressed: Is the model supported by “on-line” evidence about the temporal and logical flow of information, about the moment-by-moment processes that are claimed to take place between the presentation of auditory or written material and the achievement of understanding?

As a practical matter of psychological experimentation, these two criteria have traditionally been addressed by taking two types of measures: frequency of success on a task and performance speed. Reaction time has been one the favourite dependent variables in cognitive psychology in general and psycholinguistics in particular. The use of reaction times to evaluate theories of cognitive processes can be traced to the nineteenth century, when Donders (1868) invented the subtraction method to estimate the speed of internal cognitive processes. In more recent times, Sternberg’s (1966, 1969) use of additive factors analysis and Posner’s (1978) analysis of mental chronometry stimulated a vast amount of theoretical and experimental work and has led to a notable increase in our understanding of the nature of cognition.

Psycholinguists commonly apply the experimental techniques of mental chronometry. For instance, when studying reading, they try to draw conclusions about what representations are formed, when, on what basis, as a way of evaluating their claims about the architecture and operation of the reading system. Evidence for their conclusions has traditionally come from the speed and accuracy of responses in laboratory tasks such as lexical decision, word naming, self paced reading, question answering, sentence verification, etc. While the evidence that these tasks provide has greatly increased our understanding of the process of language comprehension, they have not always proved adequate to discriminate between competing theoretical

proposals. To take just one example: Some theorists adopt modular positions, following Fodor (1983) (e.g., Frazier & Rayner, 1982; Frazier, 1987); other theorists advocate more interactive positions (Marslen-Wilson & Tyler, 1987; MacDonald, Pearlmutter, & Seidenberg, 1994; Tanenhaus & Trueswell, 1995). Those who push modularity argue that certain types of information must be used and certain types of representations must be built in order for other types of information and representations to come into play. Those who argue for interactive processing envision a far less differentiated representational vocabulary and a far less constrained interplay among different types of information. This modular/interactive contrast would appear to have clear implications about the logical and temporal sequence of distinct processes in sentence comprehension. But although traditional measures of comprehension accuracy and speed have provided informative tests of these implications (see Mitchell, this volume), they have not provided evidence that settles the crucial questions to everybody's satisfaction.

Part of the problem with traditional methods is their relatively coarse granularity. Knowing how long it takes to read a sentence, or even a word, does not tell the researcher how long any particularly component process took. More diagnostic evidence comes from patterns of eye movements observed while reading text for comprehension or memory – what words are fixated, how long each fixation lasts, how often the eyes regress to previous part of the sentence, etc. (see Von Gompel et al., this volume, for an illustration of how the finer granularity of eye tracking measures can shed light on the underlying processes of comprehending anaphors).

Another part of the problem with traditional measures (and with many uses of eye

tracking) is their lack of specificity. An increase in comprehension time or a disruption in the eye movement record is just an increase in time. It does not, by itself, carry any sort of signature about what processes gave rise to the disruption. Sometimes (e.g., Meseguer, Carreiras, & Clifton, 2002) the location or pattern of eye movements can carry hints about what processes are going on at some particular point in time: The eyes may well go to what the reader is thinking about at any moment in time. The visual world paradigm of measuring eye movements to visual scenes during listening (Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995) similarly relies on the apparent fact that listeners tend to look at the referent of what they are hearing. Under this analysis, it can provide quite specific information about what a listener thinks a word or sentence refers to moment-by-moment (see Boland, this volume). Potentially even more diagnostic information can come from measuring brain activity during reading or listening. Measures of evoked potentials (ERPs) can arguably provide information about what processes are taking place as well as when they occur (cf. Van Berkum, this volume; Osterhout et al., this volume). Such measures, as well as measures of functional brain imaging, can provide information about what is happening in the sentence comprehension process, as well as (at least for ERP) when it is happening.

Measures of brain activity such as ERP and fMRI, coming from the new interdisciplinary field of cognitive neuroscience, can in principle do even more. They can ground the cognitive processes of language comprehension, previously treated largely as abstract information processing operations, in the neural underpinnings of the brain (e.g., Posner & Raichle, 1994; Gazzaniga, 2000). Knowing what brain structures are involved in computing different kinds of linguistic information and when they do it

can place some constraints on what categories of cognitive processes are involved in different aspects of language comprehension. If two language comprehension phenomena involve different regions of the brain, they necessarily engage at least partly distinct cognitive processes; if two phenomena involve the same regions of the brain, they may involve overlapping processes (see Fiebach, et al., this volume, for an example of this reasoning). Further, knowing what linguistic and non-linguistic tasks involve which brain regions should place some constraints on the nature of the processes that engage these brain regions.

The methodological advances provided by various uses of eye-tracking and measures of brain activity will not, by themselves, solve the problems of identifying the cognitive processes underlying language comprehension. They have to be combined with careful theoretical analyses of how the measures might be related to the presumed underlying processes (see Boland, this volume, and Tanenhaus, this volume, for discussions of “linking hypotheses”) and used in theoretically sophisticated experimentation. With the goal of highlighting current progress in using these new on-line methodologies and stimulating future progress in their use, the organizers of the 8th annual meeting of Architectures and Mechanisms of Language Processing, which took place September 19-21 in Costa Adeje, Tenerife, Spain, invited several distinguished researchers to present overviews of how eye-tracking and cognitive neuroscience measures are advancing our knowledge of language comprehension. Each of these researchers was asked to consider the following questions in preparing their presentations:

- What is an on-line process?
- Why is on-line processing a very important theoretical issue?

- Are eye-tracking and ERP good and useful on-line measures?
- Have these technologies helped theoretical knowledge advance?
- What theoretical debates have these technologies promoted?
- What theoretical questions have they helped us to answer?
- What NEW theoretical questions can be asked with these technologies?

The resulting presentations appear as chapters in the present volume. They are complemented by written versions of several papers and posters that were presented at AMLaP. The editors of the present volume made a (sometimes arbitrary!) selection of papers and posters that illustrated informative uses of eye-tracking and brain activity measures and invited their authors to submit them to this book. The results, we trust, show that substantial progress is being made in understanding the on-line nature of language processing, and should stimulate even further progress.

We turn to a brief overview of the on-line measures emphasized in this book, and then return to an attempt to highlight the contributions made in the individual chapters. Readers familiar with the basics of eye-tracking and measures of brain activity can skip the following sections without loss.

Eye movements

Eye movement recoding has become a very popular technique, or better, a family of techniques. There are two sister techniques under the label of eye movements. One technique has been applied to measure eye movements during reading (see Rayner, 1998). The other has been used to measure the eye movements to regions of a scene while participants listen to speech related to what the scene is about (Tanenhaus, et al.,

1995). Even though in both cases eye movements are recorded, assumptions about what each technique is tapping are different (see Boland, this volume for a description of both techniques).

During reading, eyes do not sweep along a line of print, but they advance through little jumps called saccades. A target word is brought to the fovea by a saccade; the eyes then fixate on the word for something like a quarter of a second to identify it. About 90% of reading time is spent in fixations, including some regressions to an earlier misperceived word. The typical reader makes about 3 or 4 saccadic movements per second. Each movement lasts between 20 and 40 ms, and the eyes typically remain fixated for about 200 to 400 ms. About 15% of the eye movements made by typical college students are regressive, meaning they go back to material previously fixated. The continuous recording of eye movements enables researchers to identify locations and durations of fixations during reading, allowing them to draw inferences about cognitive operations during reading.

A reader's fixation patterns vary greatly over a text, depending on the linguistic characteristics of the words. In developing their early model of text comprehension based on readers' eye movements, Just and Carpenter (1980) made two assumptions, the immediacy and the eye-mind assumptions. According to these assumptions a word is the unit of processing, and processing occurs immediately and completely at the time the word is encountered (see Pickering, this volume, for a discussion of these two assumptions). Gaze duration, which is the summed duration of consecutive fixations on one word before the reader's eyes leave that word, is assumed to reflect processing time of that particular word.

A substantial amount of research on eye movements in reading was conducted early in the twentieth century (see Huey, 1908; Tinker, 1946, 1958). By mid-century, research on eye movements in reading had nearly stopped. However, prompted by the development of new methodologies and the appearance of information processing theories of cognition, the study of eye movements in reading reappeared with vigor in the last third of the twentieth century (see Rayner, 1998 for a review). Nowadays, eye movement measures have been used successfully to understand the processing of several components of language processing, such as phonological and orthographic processing (Lee, Binder, Kim, Pollatsek, & Rayner, 1999; Rayner, Pollatsek, Binder, 1998), the effects of neighbourhood (Perea & Pollatsek, 1998) the processing of syllables (Ashby & Rayner, in press), lexical ambiguity (Duffy, Morris, & Rayner, 1988), morphological processing (Pollatsek, Hyona, & Bertram, 2000), syntactic processing (Carreiras & Clifton, 1999; Frazier & Rayner, 1982; Ferreira & Clifton, 1986; Trueswell, Tanenhaus, & Garnsey, 1994), plausibility (Pickering & Traxler, 1998), discourse context effects (Altmann, Garnham, & Dennis, 1992), inference processing (O'Brien, Shank, Myers, & Rayner, 1988), etc.

The recording of eye movements during reading to answer some theoretical questions about language processing and language architecture has helped us to better understand cognitive processes involved during on-line reading. On one hand, results obtained with other laboratory techniques have generally been obtained with the eye movement technique (see Mitchell, this volume). Converging evidence enhances our confidence in the phenomena. On the other hand, due to its impressive temporal resolution and its ability to fractionate reading time into distinct components (long initial fixations,

refixations on a word, regressions to earlier words, re-reading a word after a regression, etc.) the eye movement technique provides potentially useful detailed information about what cognitive processes might be occurring at any moment in time (see Boland, this volume, and van Gompel, this volume, for illustrations). The full value of eye movement measures, however, will surely only be realized when we have a better understanding of how eye movements are controlled by various sorts of cognitive processes. Powerful and informative models of eye movement control do exist (e.g., Reichle, Pollatsek, & Rayner, 1998; *in press*), but they emphasize how the location and timing of eye movements reflect lexical processing. They largely ignore processes of sentence parsing and interpretation (see Boland, this volume, *Perea & Carreiras, in press*, and Tanenhaus, this volume, for additional discussions of the need for models that link eye movements with higher cognitive processes).

Eye movement measures have recently been applied to questions about comprehension of spoken language. Making use of an old finding of Cooper (1974) that people strongly tend to look at the referents of words they are hearing, Tanenhaus and his colleagues and students (e.g., Tanenhaus et al., 1995) have created a new industry of “visual world” studies. Participants’ eye movements are measured while they are following instructions to manipulate objects in the real world or make decisions about (or simply observe) pictures on a video screen (see Boland, this volume, for an overview). It turns out that the speed with which participants look at different objects or pictures can tell us a lot about how they use phonological information, how they create syntactic structures, how they use of typical agents, objects, etc. of verbs, how they integrate information about the visual world with the speech they are hearing, etc. The technique is yielding some very intriguing results (some of which are reported in chapters in the present

volume), and at the very least allows researchers to examine in detail the effect that having a more or less specified world to talk about has on the process of language comprehension.

ERPs

Apart from neuropsychological studies of aphasia, psycholinguistic studies have usually proceeded in isolation from studies of the brain. The development of new methods for measuring the activity of the human brain has provided new tools to explore connections between cognitive processes and neural systems. Two of the most popular methods are event related potentials (ERPs) and functional magnetic resonance imaging (fMRI).

Event-related brain potentials (ERPs) are tiny voltage changes measured at the surface of the scalp, reflecting brain activity that is triggered by sensory stimuli or by cognitive processes. This activity is normally buried in different spontaneous brain rhythms, but can be revealed by averaging techniques. Through averaging, the activity that is time-locked to the stimulus is preserved, whereas other activity cancels itself out for simple statistical reasons. This allows researchers to have a non-intrusive technique for recording signals of some brain processes. The resulting spatio-temporal map of the electrical activity has extremely high temporal resolution and, with some contentious assumptions, can be used to make inferences about what brain structures are active at any moment in time (see van Berkum, this volume, and Osterhout et al, this volume for descriptions of the method and its strengths and limitations).

By varying information processing requirements through the use of different tasks, it has proved possible to identify some features of the flow of electrophysiological events that are related to different aspects of information processing. In the case of language comprehension, different ERP components appear to correlate with specific processes. For instance, it has been shown repeatedly that violations in expectancy that slow mental operations produce powerful electrical changes. Consider the sentence “Tom used to take his toast with butter”. The last word is highly primed and easily processed when it arrives because it fits so well with the context. However, if the expectancy is violated (e.g., with “socks”) one finds a negative going wave form peaking around 400 ms after word onset (the N400) (e.g., Kutas & Hillyard, 1980, 1984; & Kutas & Van Petten, 1994). Thus, difficulty with semantic integration is associated with the N400 component.

With respect to the processing of syntactic information, two different components have been identified: a left anterior negativity (LAN) and a late centro-parietal positivity (P600/SPS “ syntactic positive shift”). The LAN is a component that with a left anterior distribution starting at 250 ms that has been registered in response to syntactic (phase structure, subcategorization, etc) and morphosyntactic violations (e.g., gender and number agreement) violations (Barber et al, this volume; Friederici, Pfeifer, & Hane, 1993; Rosler et al, 1993). The P600/SPS is a positive component (or family of distinct components) with a mainly posterior scalp distribution, characteristically starting about 500 ms after the onset of the target word (Friederici, Pfeiffer, & Hahne, 1993; Hagoort, Brown, & Groothusen, 1993; Osterhout & Holcomb, 1992; see also Osterhout et al, this volume, Barber et al, this volume, Hoen and Dominey, this volume). The P600 has been found, first, for words that are ungrammatical given the preceding sentence context

(e.g., Coulson et al, 1998; Hagoort, Brown, & Groothusen, 1993; Osterhout & Holcomb, 1992; Osterhout & Mobley, 1995), second, for words that are unexpected given the preferred reading of the preceding context (garden-path sentences) (e.g., Hagoort & Brown, 2000; Carreiras, Salillas & Barber, submitted), and third for sentences or more syntactic complexity (Friederici, Hahne, & Saddy, 2002; Kaan & Swaab, 2003).

Although ERPs have been useful in investigating the cognitive processes involved in language processing, a lot of issues remain to be resolved in the use of this technique (see van Berkum, this volume; Osterhout et al, this volume). However, many of the results obtained with this technique do seem to reveal patterns that are similar to those obtained with behavioural methods. It is likely that the new advances that we are going to see in the near future regarding a better exploitation of the electrical signals of the brain (see van Berkum, this volume) together with clever designed experiments to answer insightful theoretical questions will help us to advance our knowledge on language processing.

fMRI

Neuroimaging methods such as the functional magnetic resonance imaging (fMRI) have contributed to our understanding of the relationship between neural activity and language processing. The fMRI measures changes in blood oxygenation, which are used as indicators of where in the brain neuronal activity increases or decreases during the performance of one task compared to another. Using neuroimaging techniques such the fMRI, cognitive neuroscientists are beginning to map specific brain areas to several

components of language (e.g., orthographic, phonological, syntactic, semantic processes, etc.) (see Binder & Price, 2001 for a recent review). Clearly, neuroimaging studies are particularly important in the exploration of exclusively human mental activities as language processing, because no animal models of these functions can be obtained.

Nonetheless, it is important to bear in mind that neuroimaging techniques such as fMRI have their own limitations (see Osterhout et al, this volume). For instance, fMRI can reveal areas of the brain that are active during a particular mental function, indicating whether or not that activation is necessary for the execution of that function. But the haemodynamic response is slow, on the order of seconds, which means that fMRI has an unfortunately slow temporal resolution, too slow to capture the time course of very fast cognitive processes. Measuring the time course of processing is not, however, the only way to identify the cognitive processes involved in a task. Fiebach et al. (this volume) provide one interesting example of how fMRI can be used to gather evidence about whether two distinct tasks (attempting to understand complex sentences and ungrammatical nonsentences) involve the same or distinct processes.

Using the techniques

Each of the techniques we have discussed has its own strengths and weaknesses. Clever experimentation is needed to use them properly, as is careful and explicit theorizing, including specification of the presumed links between cognitive processes and the data that can be observed in each technique. One promising way of allowing data to constrain theory is to combine the techniques in examining one particular problem.

Sereno, Rayner, and Posner (1998) combined eye-tracking and ERPs in analysing the very early stages in the process of visual word recognition. Gordon et al. (this volume) combined the same measures in studying the comprehension of anaphors. Combining fMRI, a blood-flow technique of good spatial resolution but poor temporal resolution, with ERPs, a technique of poor spatial resolution but good temporal resolution, is another promising combination (see Osterhout et al, this volume). Knowing both the timing of operations and their neural loci will help to isolate the conditions under which a particular process is operating (see Friederici, 2002 for an example of a processing model of sentence processing based on the combined evidence of ERP and fMRI data).

Overview of the book

We had two goals editing this book: to illustrate different methodological approaches used by scientists to understand language processing, and to stimulate thought about how converging evidence from these approaches can lead to new insights and advances. Eye-tracking, in its various guises, and ERPs are the current techniques of choice; fMRI holds great promise; and the future can be expected to bring new techniques that illuminate cognitive processes and their underlying brain processes in ways we cannot now imagine. The chapters that appear in this book provide evidence that researchers can use available techniques in a variety of creative ways to probe the language comprehension process and to explore its underlying brain processes.

Mitchell

Don Mitchell sets the stage for examining how different techniques can illuminate questions of real-time processing by arguing that such questions have been with us nearly since the beginning of psycholinguistics. He argues that relatively cheap and simple techniques, such as self-paced reading, have in fact provided us with a great deal of information about on-line sentence comprehension. He provides a provocative

discussion the advantages and disadvantages of a wide variety of techniques for studying language processing and puts the new, sophisticated techniques that are the primary focus of this book in the context of other, arguably more efficient, techniques.

Pickering, Frisson, McElree, & Traxler

Pickering and his colleagues describe some basic facts about measuring eye movements during reading. Their chapter lays out cautions about linking the various measures to possible cognitive processes (e.g. the problems of identifying early and late eye-tracking measures with initial and non-initial cognitive processes). It continues by providing an overview of a substantial number of experiments illustrating the use of eye movements to investigate semantic interpretation.

Boland

Julie Boland provides an overview of how eye movements can be used to study both reading and listening. Her chapter addresses linking assumptions between eye movement data and sentence comprehension processes, which clearly are different for the two eye movement paradigms, and it discusses the strengths and limitations of each paradigm. The chapter also provides some provocative suggestions about how eye movement measures might be used to distinguish between initial structure building operations and ambiguity resolution operations, among other processes.

McDonald & Shillcock

This paper measures eye movements during reading to demonstrate that knowledge of lexical co-occurrence frequencies are used on-line during reading. Eye tracking data showed an early influence of the transitional probabilities between words on various fixation duration measures, even in a range of transitional probabilities that is much lower than previous research has demonstrated to be effective. The authors advocate a Bayesian approach to integrating transitional probabilities with frequency of occurrence,

and argue that their findings fit well with other research using various techniques (including ERP and visual world techniques) that show that language processing systems are exquisitely sensitive to statistical information.

Betancort, Meseguer, & Carreiras

This chapter is the first of several chapters that study the on-line processing of anaphora. It describes two eye-tracking experiments investigating the time course of different types of information in the assignment of an antecedent to PRO (the null pronoun in Spanish) during reading. It provides convincing evidence that PRO is bound very quickly, that plausibility plays an early role in parsing, and that there are biases toward taking the most recent NP as the antecedent of PRO when the opportunity exists (and that the parser obeys the grammar when the grammar dictates).

van Gompel, Liversedge, and Pearson

Van Gompel and his colleagues use eye-tracking during reading to tease out the time course with which the antecedent of a nominal anaphor is identified. The basic question is, how does the typicality of the antecedent (e.g. “robin” vs “goose”) of an anaphor (“the bird”) influence how the anaphor is interpreted. The research shows the power of eye-tracking measures by showing how such measures can separate out distinct processes that are conflated using methods such as self-paced reading or whole sentence reading time.

Gordon, Camblin, & Swaab

This chapter continues the series of chapters on anaphor by showing how the combined use of eye-tracking and ERPs to address important issues in anaphora resolution, e.g., the repeated name penalty and the process of extracting a singular antecedent from a conjoined or plural noun phrase. The authors argue that using both eye-tracking and ERP methods provides both confirming and complementary evidence about the

interpretation of anaphors.

Sanford, Sturt, Moxey, Morrow, & Emmott

Tony Sanford and his colleagues take a different approach to studying plural anaphora, and more generally, the conceptual representation of multiple entities. They use both eye-tracking and off-line production tasks to study how semantic aspects of the situation being described and linguistic aspects of the description can influence how potential antecedents of an anaphor are represented and accessed. Their chapter presents a strong case for the position that on-line and off-line data can complement each other in helping us understand language processing.

Scheepers & Crocker

This paper uses the visual world paradigm to examine how syntactic expectations formed during reading influence the interpretation of a following heard sentence. Listeners saw pictures depicting two events while they heard German sentences that were ambiguous between mentioning subject (agent) or object (patient) first. The sentence that had just been read was shown to influence the resolution of this ambiguity. In addition to showing that the visual world technique can shed light on just how and when interpretive ambiguities are resolved, the paper provides some hints that measures of pupil diameter may provide information about momentary processing load.

Huettig & Altmann

This paper uses the visual world paradigm to show that listeners were more likely to look at a visual foil that shares some salient physical characteristics with the referent of a target word than at foils that do not have such an identifiable physical similarity. A similar effect was observed for conceptual category membership (but not for physical properties that had to be supplied by conceptual knowledge rather than by the pictures). Further, listeners were more likely to look at the referent of the dominant meaning of a

homophone (or to an object that shared a salient physical feature with this referent) than at unrelated objects, even when the context contained some information that biased the homophone toward its subordinate meaning. These sometimes-surprising results seem to shed light on the time course of extracting semantic information from what is heard and coordinating it with knowledge of what is seen.

Brown-Schmidt, Byron, & Tanenhaus

In this final chapter on anaphora, the visual world paradigm is used here to study the discourse and reference conditions that govern the use of the demonstrative pronoun "that" (in contrast to "it"). The data show that the final interpretations of "that" and "it" differ, and that a "composite" object is a more attractive referent of either pronoun than is a pair of objects side-by-side.

van Berkum

Van Berkum provides an illuminating overview of ERP research, containing lots of practical advice about doing such research and discussing what ERP research is good for. In addition to serving as a very useful introduction to the use of ERP techniques in studying on-line language processing, the chapter illustrates how ERP research can be used very effectively to address crucial questions about the relation between discourse-level and sentence-level processing.

Osterhout, McLaughlin, Kim, Greenwald, and Inoue

This chapter complements the previous one by providing another overview of ERP methods and research. It shows how ERPs can complement other methods such as eye movements and fMRI in addressing core questions of language processing, such as the distinction between syntactic and semantic processing. Among other topics, it discusses the possible use of ERPs to localize sources, providing some promising evidence.

Further, it summarizes some provocative research on second language acquisition,

suggesting that ERP measures can identify effects of learning earlier in the course of acquiring a language than overt behavioural measures can.

Barber, Salillas, & Carreiras

This paper reports one experiment with the use of ERPs to address the processing of semantic and grammatical gender agreement violations in Spanish. It reports both a LAN and a P600 effect of similar size for both grammatical gender violations and semantic gender violations, but also reports some intriguing differences between semantic and arbitrary gender sentences when there was no violation.

Hoen & Dominey

Hoen and Dominey present some intriguing evidence about the similarity of three ERP components in natural language and in an artificial language. They provide evidence for a LAN-like effect in response to the occurrence of a symbol that indicates an upcoming reversal of the preceding sequence; an N400-like effect in response to an unexpected symbol; and a P600-like effect in response to a violation of the order in which the symbols should appear in the second half of the sequence. Generally comparable effects are shown for corresponding conventional types of violations in French sentences. Thus, they make the case that it appears to be possible to study ERPs in artificial languages whose properties can be well controlled.

Fiebach, Schlesewsky, Bornkessel, & Friederici

Fiebach and colleagues provide an interesting example of how fMRI, not generally thought of as an on-line task, can help us to understand better the on-line phenomena of processing difficult sentences and ungrammatical nonsentences. At least some behavioural tasks, e.g. acceptability rating, do not exhibit a distinction between responses to ungrammatical strings and to very difficult sentences. However, the fMRI

data indicate a clear and informative difference between the brain regions that are strongly engaged in dealing with ungrammatical vs. difficult items.

Tanenhaus

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