

# Introduction

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**Developmental Psycholinguistics: On-line methods in children's language processing**

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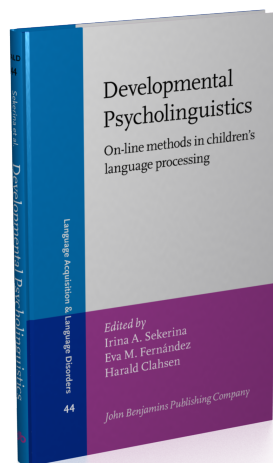
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# Introduction

Irina A. Sekerina, Eva M. Fernández and Harald Clahsen

The study of child language occupies a unique place in research on children's cognitive development. This comes as no surprise, as language is quite close to the core of what it means to be human. Children successfully learn their native language in a relatively short time and without the need for formal instruction. Language is also the main vehicle by which we learn about other people's thoughts; therefore, cognitive and linguistic aspects of human development must be intimately related.

Traditional methods of inquiry in modern linguistics and cognitive psychology have enabled us to learn a great deal about how children acquire language and the stages they go through on their way to adult competence (Pinker 1995). But empirical studies on how children's language develops published over the last 30 or 40 years have a striking characteristic in common: they treat language acquisition as a process that involves building a static database called *the grammar*, to the exclusion of the mechanisms that operate in real time when the child produces or comprehends language. The classic Competence/Performance distinction (e.g., Chomsky 1964) provides a useful framework for discussing this problem: while investigations of child language acquisition are grounded on the assumption that knowledge of language is put to work via a set of processing mechanisms (performance), the primary concern in acquisition research has been with how that principled knowledge (competence) develops. McDaniel, McKee and Cairns (1996), in their seminal book on assessing child language, described how the knowledge that constitutes competence had up until then been extensively studied, and they documented the predominance of *off-line* experimental methods, that is, techniques that prompted children to act out sentences, answer questions or provide grammaticality judgments, responses that could then be compared to those provided by adults or by older or younger children. Armed with empirical evidence of that sort, the field was able to begin to address some of the most basic questions about language development and to formulate explicit descriptions about the nature of developmental sequences.

The era of traditional research on language acquisition, captured so well in the volume by McDaniel et al. (1996), has grown into a mature area of inquiry whose insights have led to a rich understanding about the development of linguistic competence. But times have changed, as we enter a new era that takes a “dynamic processing approach” to the study of language development (Trueswell this volume). We are witnessing a growing interest in the mechanisms that underlie production and comprehension abilities in children, a shift from a focus on competence to a focus on performance. This enterprise has been significantly facilitated by recent advances in technologies that permit tracking behavior at a very fine temporal resolution, methods that have been successfully and extensively applied to study language processing in adults. Such new techniques, which we will collectively refer to as *on-line*, measure reaction times, track eye gazes, examine brain activity. Some of these methods, like self-paced reading, self-paced listening, and cross-modal priming benefit from having a long-standing tradition in the study of adult language processing. Others, like eyetracking and neurophysiological techniques (Henderson & Ferreira 2004; Trueswell & Tanenhaus 2005; Carreiras & Clifton 2004), are newer but quite powerful additions to the experimental toolkit, particularly because they provide the means to study in great detail very early phases of processing, and because they rely little on conscious attention to or metalinguistic awareness of linguistic stimuli.

On-line methods have made their way into language acquisition research with a truly amazing speed. A mere 10 years ago, as documented by Cecile McKee (1996) in her chapter on on-line methods in child language research, reaction time methods (cross-modal priming in particular) dominated the scene, neuroimaging hardly having a presence. Eyetracking was fully absent from McKee’s chapter.

When applied to the study of child language, on-line methods permit researchers to observe the interaction of grammar principles (competence) and behavioral limitations and/or preferences (performance), with a greater level of detail and a greater number of perspectives than ever before. We can now investigate how children coordinate multiple sources of information in real time and arrive at sentence meaning using information extracted not only from the words and structure of the sentence but also from the nonlinguistic context. The application of on-line methods also makes it possible to test children’s performance limits, to separate performance from competence in assessing children’s static and developing linguistic knowledge, an approach that permits building and testing theories about how children’s language processing contributes to their acquisition of language (Fodor 1998).

The growing importance of on-line methods in child language research was evident at the forum that brought this volume into being, the *Workshop on On-*

*Line Methods in Children's Language Processing* held at the Graduate Center of the City University of New York in March 2006. Workshop participants discussed and evaluated questions about the design, methodology, ethics, and practicalities of conducting such studies with children, and speculated on future directions for the emerging field of *developmental psycholinguistics* (Trueswell this volume) and its subfield, *developmental cognitive neuroscience* (Männel & Friederici this volume). In assembling this volume, we asked distinguished researchers – pioneers in the application to child language research of a range of on-line methods – to provide overviews on how changing research paradigms are advancing our understanding of language processing in children. While the overarching theme of this volume is methodological in nature, the collection of chapters achieves a broad coverage also of linguistic and developmental areas by including research on both comprehension and production; by addressing sound-, word- and sentence-level representations; and by discussing aspects of acquisition throughout the entire span of early childhood, from infancy to the elementary school years. The chapters in the volume are dedicated to reaction time methods (Clahsen); eyetracking in its two main forms, free-viewing (Trueswell; Snedeker & Thothathiri) and looking-while-listening (Fernald, Zangl, Portillo & Marchman); and event-related potentials (ERPs; Männel & Friederici). Functional neuroimaging (fMRI), magnetoencephalography (MEG) and optical imaging have yet to make their way into developmental psycholinguistics and, therefore, are not represented in the volume.

We have chosen to group and order the chapters in terms of the methods they focus on, starting with methods examining behavioral responses and followed by methods analyzing event-related potentials and methods tracking eye gazes. Closing the volume, Chapter 6 provides a historical backdrop and speculates about the future of the field.

Chapter 1, “Behavioral methods for investigating morphological and syntactic processing in children” (Harald Clahsen), describes and evaluates experiments using response-time measures to examine processes involved in children's processing of sentences and inflected words. The chapter builds on Cecile McKee's documentation (1998) of on-line methods in child language research and presents an updated overview focusing on techniques that Clahsen, Felser, and the research group at the University of Essex have used to examine how children process complex syntactic phenomena and morphologically complex words in real time. The chapter introduces five criteria against which the various methods for studying children's on-line language processing can be assessed. These criteria are: (a) time sensitivity of the technique, (b) naturalness of stimuli presentation, (c) child appropriateness of the technique, (d) linguistic versatility, and (e) filed compatibility. It then provides an overview of behavioral tasks for in-

vestigating children's grammatical processing in production and comprehension. Three experimental techniques are presented in detail: *speeded production*, used to examine automatic processes involved in the spoken production of inflected words; *self-paced listening*, employed in examining children's processing of temporarily ambiguous sentences, specifically relative-clause attachment preferences; and *cross-modal priming* used to determine whether dislocated constituents (e.g., fronted *wh*-phrases) are reactivated at corresponding gap positions during processing. Despite the availability of ERPs and eyetracking, behavioral methods such as the ones outlined by Clahsen still have an important place in developmental psycholinguistics, as these techniques can be applied to study a range of complex and interesting language phenomena, providing time-sensitive measures that require minimal technical equipment.

Chapter 2, "Event-related brain potentials as a window to children's language processing: From syllables to sentences" (Claudia Männel and Angela Friederici), provides an overview of the comprehensive research program to study neurocognition of language, cortical networks and cognitive functions, and language acquisition using ERPs at the Institute of Neuropsychology of the Max-Planck Institute for Human Cognitive and Brain Science in Leipzig. Angela Friederici, head of the Institute, is a leading researcher in applying measures of brain activity in adult sentence processing and has proposed an influential neurocognitive model of language and its extension to the area of language acquisition, which she herself calls *the developmental cognitive neuroscience of language* (Friederici 2000, 2002).

In their chapter, Männel and Friederici describe the successful application of ERP methods to study language acquisition in infants from birth to three years. The chapter describes five ERP components closely linked to language, and how they reflect the processing of phonological, semantic, and syntactic information in progressively older children, compared to adults. Männel and Friederici outline ERP research on a number of landmarks of child language acquisition and identify neural correlates for developmental stages in auditory language comprehension. The research findings summarized in Chapter 2 include (a) work on syllable and stress discrimination in infants using the passive oddball paradigm, (b) investigations of the N400 component as a reflex of phonotactic knowledge, early word learning and knowledge of selectional restrictions for verbs, (c) research measuring sensitivity to sentence-level prosodic cues with the Closure Positive Shift (CPS), and (d) studies eliciting an adult-like biphasic ELAN-P600 component in response to phrase structure violations at the sentence level. Männel and Friederici draw the chapter to a close by demonstrating how ERP components can be used to identify infants at risk for later developing language problems, such as Specific Language Impairment (SLI) and dyslexia. The technique therefore con-

stitutes a new diagnostic tool for very early identification of children who would benefit from intervention.

Chapter 3, “Using eye movements as a developmental measure within psycholinguistics” (John Trueswell), is the first of the three chapters dedicated to eyetracking. Trueswell describes and evaluates free-viewing eyetracking – also known as the visual world paradigm and the world-situated eye-gaze paradigm – to study sentence-level comprehension in toddlers and preschool-age children. John Trueswell and his team at the Institute for Research in Cognitive Science at the University of Pennsylvania were the first to adapt this method to investigate how 5-year-old children comprehend syntactically ambiguous sentences and how sentence processing mechanisms develop (Trueswell, Sekerina, Hill & Logrip 1999). Trueswell begins his chapter with a history of eyetracking in adult research and continues with a technical description of head-mounted, remote and “poor man’s” eyetrackers; an explanation of calibration procedures; and remarks about eyetracking data analysis. Trueswell then describes three linking assumptions critical for making valid inferences about what children’s eye gaze patterns reveal about the development of sentence processing mechanisms, and, in particular, referential processing.

In a second part of his chapter, Trueswell discusses recent findings from early oculomotor development, visual search, and neurocomputation models of visual attention, all of which are informative with respect to understanding characteristics of spatial attention from infancy until the age of 3. Such discussion provides a solid backdrop for Trueswell’s review of the experimental evidence accumulated over the past decades about using eye movements to infer how children resolve prepositional phrase attachment ambiguities, pronominal reference, and quantifier scope, as well as the influence of discourse factors in referential communication tasks.

Chapter 4, “How infants look as they listen: Using eye movements to monitor on-line comprehension by very young language learners” (Anne Fernald, Renate Zangl, Ana Luz Portillo and Virginia Marchman), takes on a complementary approach to the foundational chapter by Trueswell, walking the reader through a detailed description of the listening-while-looking paradigm pioneered by Anne Fernald, the leading author of this chapter, and the Stanford University Center for Infant Studies. Listening-while-looking (LWL) is a version of free-viewing eyetracking adapted for use with infants. The technique was developed out of a desire to overcome a number of shortcomings of commonly used off-line methods to examine language comprehension by infants, such as diary studies, parental-report checklists of vocabulary growth, experiments on word learning, and early versions of the preferential-looking paradigm. These methods do not tap into the real-time properties of spoken language and reveal little about the child’s

developing efficiency in processing continuous speech during comprehension. The LWL method involves videotaping infants' eye movements and coding these at the finest level of resolution possible in relation to relevant points in the speech signal. The technique can be used to collect eye movement data from infants as young as 14 months, comparable in reliability and precision to data from adult studies that require technically much more sophisticated eyetracking technology. The chapter focuses on the LWL paradigm at a functional level and discusses the logic of each step in the procedure, from preparing and running an experiment to coding eye movements and analyzing the data for several different measures of efficiency in spoken word recognition in infants.

Chapter 5, "What lurks beneath: Syntactic priming during language comprehension in preschoolers (and adults)" (Jesse Snedeker and Malathi Thothathiri) – the third and final contribution on eyetracking – describes how to use a "poor man's" free-viewing eyetracker in testing a particular theoretical problem in the area of language acquisition, i.e., the nature of young children's abstract grammatical representations. Snedeker and Thothathiri exploit the phenomenon of structural priming in production, well known in adult psycholinguistics, to study structural priming during spoken language comprehension in 3- and 4-year-old children.

Snedeker and Thothathiri's starting point is a brief summary of three prior experiments that extend to young children basic findings in structural priming in adult production. This line of research suggests that children older than 4.5 show robust evidence for abstract structural representations of both dative and transitive constructions, while 3-year-olds and younger 4-year-olds do not. Snedeker and Thothathiri set out to test the hypothesis that even younger preschoolers do indeed construct abstract structural representations, seeking evidence of this in their eye movement patterns. The remainder of the chapter reports a series of three experiments employing the "poor man's eyetracker" to examine structural priming in sentences with verbs such as *give* and *hand*, which license dative alternation (V NP NP vs. V NP PP). As expected, eye movement patterns for young 4-years-olds and 3-year olds – as for adults and 4-year-olds – show an effect not only of lexical within-verb priming but, critically, also of abstract between-verb priming for dative sentences.

The final chapter of the volume, "Language acquisition research. A peek at the past: A glimpse into the future" (Helen Smith Cairns), reviews a range of landmark studies in language acquisition research, providing a historical perspective that promotes a better understanding of the significance of the shift in focus from competence toward performance, from off-line to on-line paradigms. Cairns tells the story of how the (still young) field of research on language acquisition has evolved, from early fieldwork studies focusing on the regularities of speech pro-

duced by children through studies employing sophisticated off-line techniques to probe underlying linguistic knowledge, though studies taking advantage of on-line techniques to understand performance mechanisms in children. The chapter addresses the complexity of the relationship between theory and practice. Theories have driven experimental innovation, while at the same time the availability of experimental techniques promotes the development of new theories.

Cairns discusses the early interest on the problem of how an underlying grammatical system is acquired. The realization that the speech produced by children vastly under-represents what they might know led to a shift in interest on how implicit knowledge of language develops, an undertaking sustained by the increased sophistication of theories of grammar.

Cairns then provides a brief history of how psycholinguistics developed into a ripe area of inquiry exploring the mechanisms employed in the production and perception of language in adults. As for children, Cairns notes that the preoccupation with competence in language acquisition research, along with a concern to control “performance factors” (such as effects of memory or task demands), resulted in a paucity of studies of children’s performance.

But, as this volume represents, and Cairns discusses at length in her chapter, new questions are emerging that directly address the nature of children’s language processing. Cairns reviews a range of studies – some discussed elsewhere in this volume, some presented at the Workshop, and others sampled from the literature – that are addressing questions about whether children construct representations that resemble those constructed by adults, about how children revise initial parses, about how children’s memory spans limit their performance, about how cross-linguistic research is identifying universal tendencies in child language processing, and about how some of these techniques can be employed for the early detection of language disorders.

To conclude her chapter, Cairns offers some speculations about what the future holds for research in child language development, echoing a number of the other contributions to this volume when stressing the need for multiple and complementary methodological approaches. Progress is called for in particular with respect to the question of how children operate on input to create new grammars, on how adult-like processing skills develop, and on the underlying neural organization. We hope that this volume will lead to innovation in these and related questions.

We cannot understate the importance of the source for this volume, the *Workshop on On-Line Methods in Children’s Language Processing* held at the Graduate Center of the City University of New York, March 22–23, 2006. The abstract proceedings for the papers and posters presented at the Workshop are presently available at <http://www.qc.cuny.edu/~efernand/childlang/>. The first joint scien-

tific gathering specifically dedicated to the emerging field of experimental developmental psycholinguistics, the Workshop gathered specialists in language acquisition, psycholinguistics, neuroscience, and speech-language pathology. Ostensibly, the objective was to provide a forum for discussing the advantages and shortcomings of using on-line methods to study language processing in children, ranging from behavioral methods to paradigms involving eyetracking, to neurophysiological techniques. Beyond discussing methodology, the Workshop initiated dialog between an international and interdisciplinary group of scholars, who were afforded the opportunity to reflect on past landmarks of research in language acquisition, summarize the current state of emerging research on language processing in children, and engage in lively debates about future directions.

The current volume offers six papers loosely based on talks delivered at the Workshop. We have asked the authors to concentrate on methodological matters, but they have gone beyond that directive and produced chapters that serve as more than introductions to experimental paradigms, since they address some of the complex theoretical debates as well as provide a solid overview of child language development.

We are happy to take this opportunity to express our gratitude to those who made the Workshop and this volume possible.

First, we thank the 120 presenters and attendees from the United States, Europe, Japan and Australia for their thought-provoking papers and posters.

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