Lexical priming and semantic integration reflected in the event-related potential of 14-month-olds

Manuela Friedrich[CA] and Angela D. Friederici

Max Planck Institute for Human Cognitive and Brain Sciences, 04303 Leipzig, Germany

[CA]Corresponding Author: friedri@cbs.mpg.de

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This study investigates by means of the event-related brain potential whether mechanisms of lexical priming and semantic integration are already developed in 14-month-olds. While looking at coloured pictures of known objects children were presented with basic-level words that were either congruous or incongruous to the pictures. The event-related potential of 14-month-olds revealed an early negativity in the lateral frontal brain region for congruous words, and a later N400-like negativity for incongruous words. These results indicate that both lexical priming and semantic integration are already present as early as 14 months. *NeuroReport* 16:653–656 © 2005 Lippincott Williams & Wilkins.

Key words: Development; Event-related potentials; Lexical–semantic processing; N400

INTRODUCTION

The present study focuses on the question of how existing lexical–semantic knowledge affects speech processing in 1-year-olds, particularly how the presentation of known objects facilitates or hampers the processing of spoken words. In a recent study, using a cross-modal event-related potential (ERP) priming paradigm with coloured pictures and slowly spoken basic-level words, a facilitation effect for word processing was found in 19-month-olds. Words that were congruous to the pictures elicited more negative responses than incongruous words over the lateral frontal brain region between 150 and 400 ms after stimulus onset [1]. In uni-modal studies with 11, 14 and 20-month-olds, negative responses within this time range indicated lexical familiarity with known words [2–5]. In the cross-modal paradigm, lexical familiarity was held constant by presenting exactly the same words in each condition. Instead, preactivation of lexical representations differed as a result of processing the picture context. This lexical priming in turn preactivates phonological representations. Thus, the effect represents improved phonological processing by cross-modal lexical priming. The phonological–lexical priming effect was followed by a broadly distributed negativity for the incongruous compared with the congruous picture–word pair. This effect most likely represented an N400 [6], reflecting the effort of semantic integration of a stimulus into the current context [7] as shown in adults and in children [8–11]. The occurrence of an N400 in 19-month-olds indicates that semantic priming (i.e. ease or difficulty of integration into semantic context) is already present at that age [1].

The processing of word-like stimuli in meaningful contexts has also been explored in 14-month-olds [12]. In this study, two different pseudowords ('gibu' and 'bidu') were used by parents to name novel objects in a training phase. Although the post-training ERP differed between pseudowords that matched the trained name of the object and those that did not match the object, there was no evidence for either lexical priming or semantic integration effects. The absence of these effects in 14-month-olds, and their presence in 19-month-olds, might indicate that their processing mechanisms develop between the age of 14 and 19 months. However, several differences exist in the methodology between the two studies, which may be responsible for the observed differences between the age groups. For this reason, in the present study, we investigated whether 14-month-olds already show lexical priming and semantic integration effects in their ERP when applying the same picture–word priming paradigm as that used in 19-month-olds.

MATERIALS AND METHODS

Participants: A total of 37 children were measured when they were 14–15 months old. Their behaviour was continuously observed via a video-monitor to determine whether they were looking at the pictures. Data from seven infants were excluded from the analyses because these children either did not stop moving excessively or, during long periods, were not looking at the pictures. In the analyses presented here, we included only those children who were looking at the pictures in at least 70% of the trials and met the criteria of 20 artefact-free trials per condition. A total of 30 children (13 boys, 17 girls, mean age: 14 months 11 days) entered the final analyses. On average, these children were looking at the monitor during 84% of the whole session.

Stimuli: Pictures were clearly identifiable coloured illustrations of single objects that 1-year-olds already know. Words were slowly spoken basic level names (mean word length: 1083 ms), which are known to be first acquired by infants. They were presented via a loudspeaker with an intensity of 65 dB sound pressure level. Each word occurred in both congruous and incongruous picture context.

Procedure: Children were seated in front of a TFT-LCD computer screen (distance about 1–1.5 m) in a sound insulated experimental room. The total experimental session lasted about 12 min. At each trial a picture appeared for 4000 ms on the screen. After an interval of 900 ms from picture onset, an indefinite article was acoustically presented, which 1000 ms later, while the picture was still seen on the screen, was followed by a word or a word-like stimulus. Words were either correct names of the pictured objects or names of other objects, that is, either congruous or incongruous to the picture meaning. Incongruous words were not semantically related to the pictured objects (e.g. house–sheep or apple–shoe). Congruous and incongruous words presented to the same picture always differed in their first phonemes. Additionally, pseudowords and nonwords were presented. Here, we report only data from word stimuli.

Event-related potential recording and averaging: The electroencephalograms (EEGs) were continuously recorded from silver–silver chloride electrodes at sites F7, F3, FZ, F4, F8, FC3, FC4, T3, C3, C4, T4, CP5, CP6, T5, P3, PZ, P4, T6, O1, O2 and left and right mastoids (A1, A2) attached to an elastic electrode cap. During the recordings, the ERP electrodes were referenced to CZ. The electrooculogram was recorded bipolar. Electrode impedances were mostly below 10 kΩ, at least below 20 kΩ. The EEG was amplified with PORTI-32/MREFA, and digitized online at a rate of 500 Hz (digital filter from DC to 125 Hz).

Offline, the EEG was re-referenced to the average of left and right mastoids (A1, A2). A zero-phase digital band-pass filter ranging from 0.3 to 20 Hz (−3 dB cutoff frequencies of 0.43 and 19.87 Hz) was applied to increase the signal-to-noise ratio by removing slow drifts and muscle artefacts. All trials were individually checked for artefacts. Blink and horizontal eye movements were corrected by a PCA-based computer algorithm. All other artefacts were rejected manually. The mean number of accepted trials was 25. It did not differ between the conditions. Epochs of 1600 ms from word onset were averaged according to a 200 ms prestimulus baseline.

Data analyses: Mean amplitudes for consecutive time windows of 100 ms duration within 200–1400 ms after stimulus onset were calculated for each condition at each electrode site. To assess incongruity effects and topological aspects of these effects, three-way repeated-measures analyses of variance (ANOVAs) with Condition (congruous, incongruous), Region (F7/F8, F3/F4, FC3/FC4, T3/T4, C3/C4, CP5/CP6, P3/P4, T5/T6) and Hemisphere (left, right) as

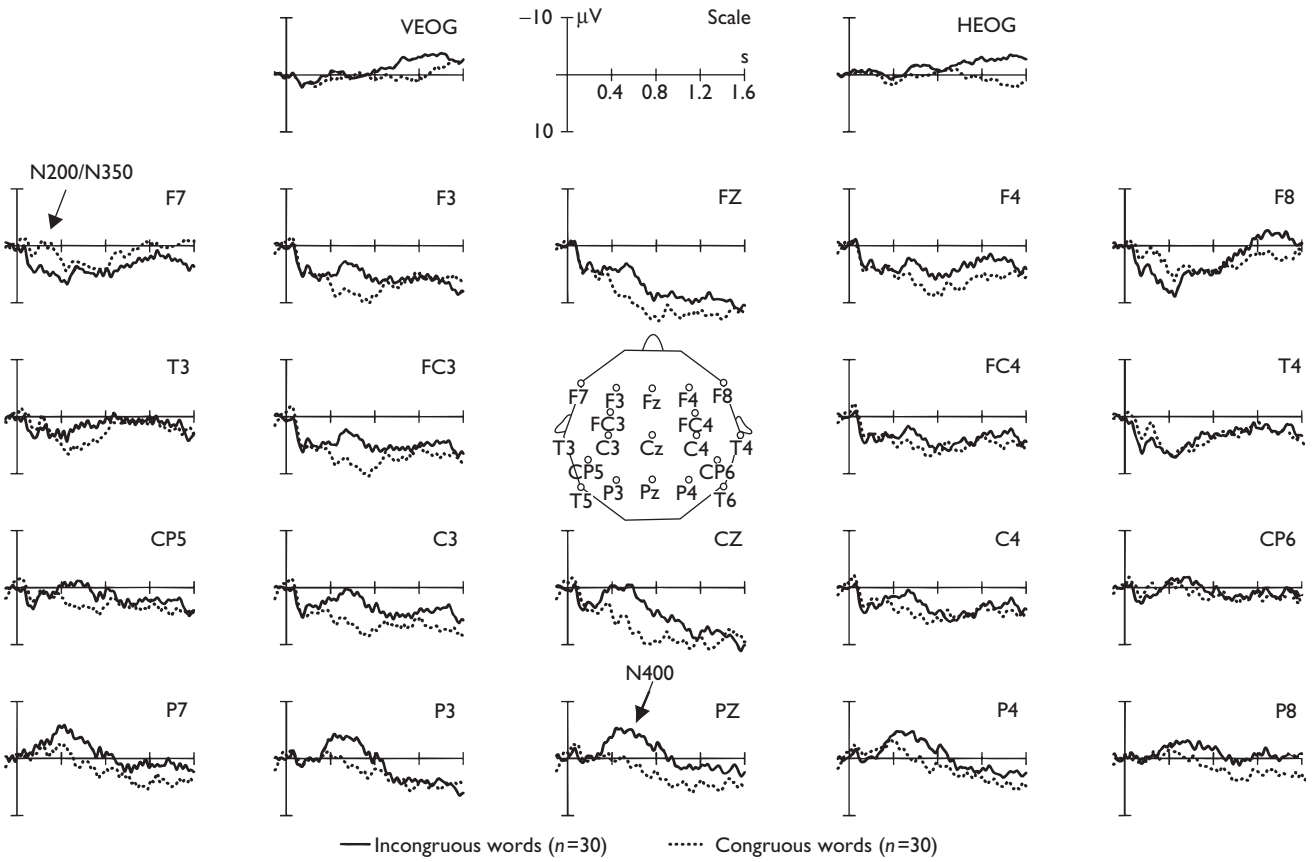

Fig. 1. Event-related potentials of 14-month-olds on slowly spoken words during picture–word matching.

within-subject factors were carried out. For midline sites, two-way ANOVAs with word Condition (congruous, incongruous) and Region (FZ, CZ, PZ) were performed. Significant interactions including Condition were further analysed by one-way ANOVAs. In all ANOVAs, the Greenhouse–Geisser correction [13] was applied, whenever there was more than one degree of freedom. Here, we report uncorrected degrees of freedom, and adjusted *p*-values.

RESULTS

The ERP of 14-month-old children on slowly spoken words (Fig. 1) is dominated by a frontocentrally distributed slow positive wave. It is overlapped by small negativities, N200 and N350, both of which typically occur in the ERP on word stimuli in 1-year-olds [1–5]. Differences between the responses of congruous and incongruous words are already present in these early time ranges. This was indicated by interactions of Condition with Region within 200 and 300 ms and within 300 and 400 ms (see Table 1 for the results of the three-way and the two-way ANOVAs). During these time windows, the responses on congruous words were more negative than the responses on incongruous words in the lateral frontal region (see Table 2 for the results of all one-way ANOVAs). Interactions of Condition and Region were also present from 400 to 500, and 500 to 600 ms. While in the right lateral frontal brain region congruous words still produced significantly more negative responses between 400 and 500 ms, other brain regions displayed a reverse pattern. From 400 to 800 ms, a parietal distributed negative wave was present for incongruous but not for congruous words. In addition to the interactions of Condition with Region, Condition main effects with the incongruous word condition being more negative than the congruous one, were observed from 400 to 600 ms. Condition main effects without interactions from 600 to 800 ms indicated that during later time windows this negative incongruity effect becomes still more evenly distributed. At midline, Condition main effects occurred from 400 to 1000 ms. No interaction occurred with Condition at midline, although from 400 to 900 ms the negative incongruity effect seemed to be stronger over the central and the parietal than over the frontal region (see Fig. 2 for the spatial distribution of the difference wave).

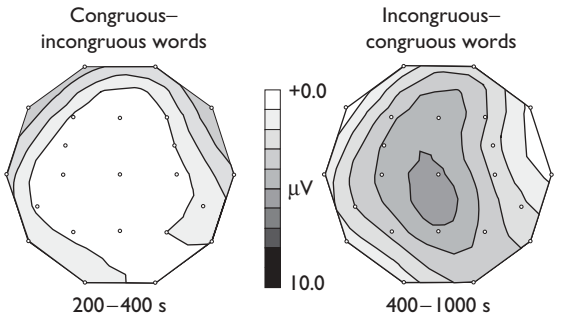

Fig. 2. Spatial distribution of the two effects: more negative responses for congruous words in the lateral frontal brain region from 200 to 400 ms (left), and more negative responses for incongruous words with a centro-parietal focus from 400 to 1000 ms (right).

Table 1. Condition effects within three-way and two-way ANOVAs (midline).

Time window (ms)	Condition (three-way ANOVA) F(1,29)	Condition × Region (three-way ANOVA) F(7,203)	Condition (two-way ANOVA) F(1,29)
200–300		2.811*	
300–400		3.444*	
400–500	4.192*	2.950*	11.801***
500–600	8.608**	3.209*	13.382****
600–700	6.697*		13.784****
700–800	3.979°		7.984***
800–900			6.733*
900–1000			6.000*

°$p < 0.06$,
*$p < 0.05$,
**$p < 0.01$,
***$p < 0.005$,
****$p < 0.001$.

Table 2. Condition effects within one-way ANOVAs for the single electrode sites for the time windows with interactions including condition.

Time window (ms)	Congruous condition more negative than incongruous F(1,29)	Incongruous condition more negative than congruous F(1,29)
200–300	F7: 11.623**	
	F8: 8.031**	
300–400	F8: 8.896**	
	F7: 6.573*	
400–500	F8: 5.363*	T3: 6.981*
		F3: 6.814*
		FC3: 5.353*
		C3: 5.850*
		P3: 6.162*
500–600		T4: 12.646****
		F3: 9.868****
		FC3: 9.057***
		C3: 9.025***
		P3: 7.797***
		CP5: 5.082*
		C4: 5.710*
		P4: 4.657*

*$p < 0.05$,
**$p < 0.01$,
***$p < 0.005$,
****$p < 0.001$.

DISCUSSION

The present study was intended to explore mechanisms of lexical–semantic processing in 14-month-old children. In particular, we wanted to know whether electrophysiological correlates of lexical priming and semantic integration, which have been observed in 19-month-olds [1], are already present in earlier ages. By applying a picture–word paradigm to 14-month-olds, we found similar differences between the processing of congruous and incongruous words in 14-month-olds as reported for 19-month-olds. The more negative response in the lateral frontal brain region on exactly the same words, when presented in congruous picture context than when presented with incongruous pictures, indicates that the 14-month-old children, like 19-month-olds, create lexical expectations from the picture content. Thus, lexical priming is already present at this age. In addition, children at the age of 14 months showed a

parietal negativity on words presented in semantically incongruous picture context. The occurrence of an N400-like incongruity effect in the difference between incongruous and congruous words indicates that mechanisms of semantic integration are present in 14-month-olds, and that these mechanisms are affected by semantic priming. The semantic priming effect, however, included not only centroparietal but also frontal brain regions. We interpret this involvement of more anterior brain regions as enhanced image-specific semantic processing in 1-year-olds. This is in line with studies on picture processing in adults, which found anterior negativities to be a correlate of visually-based processing of semantic incongruity [14,15].

CONCLUSION

These results of the present study indicate that both mechanisms of lexical priming facilitating acoustic–phonological processing and mechanisms of semantic priming facilitating integration into semantic context are already present in 14-month-old children.

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