Research Article

INCIDENTAL LANGUAGE LEARNING: Listening (and Learning) out of the Corner of Your Ear

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Abstract—*Two experiments investigated the performance of first-grade children and adults on an incidental language-learning task. Learning entailed word segmentation from continuous speech, an initial and crucial component of language acquisition. Subjects were briefly exposed to an unsegmented artificial language, presented auditorily, in which the only cues to word boundaries were the transitional probabilities between syllables. Subjects were not told that they were listening to a language, or even to listen at all; rather, they were engaged in a cover task of creating computer illustrations. Both adults and children learned the words of the language. Moreover, the children performed as well as the adults. These data suggest that a statistical learning mechanism (transitional probability computation) is able to operate incidentally and, surprisingly, as well in children as in adults.*

Language acquisition by children is an instinctive, and apparently effortless, process, which typically occurs amidst a vast array of other sensory and intellectual experiences. The process of acquiring language is thus *incidental* in the sense that the child's primary task is presumably understanding, rather than acquiring, language (e.g., Chomsky, 1975; Krashen, 1985). Moreover, language is acquired by infants and young children, who are unlikely to be engaged in explicit, conscious learning. However, little research has examined the characteristics of incidental learning pertinent to the process of children's language acquisition.

Outside the realm of natural language acquisition, there are several experimental literatures that have investigated the incidental learning of complex patterns. One potentially relevant phenomenon is *implicit learning*. Introduced by Reber (1967), implicit learning is claimed to involve the unconscious and unintentional acquisition of abstract information (see Reber, 1993, for an extensive review). Although a number of controversies have emerged in discussions of implicit learning (e.g., Dulany, Carlson, & Dewey, 1984; Shanks & St. John, 1993), it is clear throughout this literature that subjects are, at least to some degree, able to induce certain aspects of the structure of patterned stimuli incidentally.

A second set of phenomena that may bear on the process of incidental language learning is found in the literature on frequency estimation. It has been suggested that the frequency of events present in the environment is a fundamental type of information that is encoded in memory incidentally (see Hasher & Zacks, 1984, for an overview). Information about event frequency is acquired by humans across a broad range of natural and experimental situations, and is maintained even when there is no reason to remember the events in question (Hasher, Zacks, Rose, & Sanft, 1987).

Among the many features of implicit learning and frequency estimation, two characteristics in particular suggest that the phenomena, and their underlying mechanisms, may be related to one another. First, both types of learning appear to be age-invariant, with young grade-school-aged children and adults demonstrating equivalent performance on these tasks (e.g., N.R. Ellis, Palmer, & Reeves, 1988; Hasher & Chromiak, 1977; Roter, 1985, cited in Reber, 1993). Such findings of age invariance stand in sharp contrast to most other phenomena in developmental psychology, for which the most obvious and gross generalization is that performance improves with age. A second shared characteristic appears in the types of mechanisms hypothesized to underlie these two types of learning. Knowledge of event frequency involves statistical computations, performed either on the input or across memory representations. Similarly, it has been argued that implicit-learning phenomena are based on learning mechanisms that capitalize on the statistical structure of the input (e.g., Cleeremans, 1993; Perruchet & Pacteau, 1990; Reber, 1993; Servan-Schreiber & Anderson, 1990; Stadler, 1992).

To what extent can an understanding of these two learning processes shed light on natural language acquisition? Traditionally, the process of language acquisition has been viewed as distinct and qualitatively different from learning of other types (e.g., Chomsky, 1965; Osherson & Wasow, 1976). Most models of acquisition are formulated in specifically linguistic terms, with little attempt to relate even the earliest stages of this process to mechanisms capable of acquiring other types of patterned information.

However, recent findings in language acquisition focus on some of the same characteristics as do the literatures on implicit learning and frequency estimation. Unlike most other aspects of cognitive development, language acquisition does not favor adults over children. Rather, the initial stages of language acquisition are characterized by age invariance. In later stages, learners who began as children surpass those who began as adults (e.g., Johnson & Newport, 1989; Krashen, Long, & Scarcella, 1982; Newport, 1990; Slavoff & Johnson, 1995). Moreover, recent computational models of language acquisition suggest that at least some pertinent language-learning mechanisms may induce structure from the input using statistical methods similar to those suggested by incidental-learning research (e.g., Brent & Cartwright, 1996; Christiansen, 1994; Cleeremans, Servan-Schreiber, & McClelland, 1995; Elman, 1990; Mintz, Newport, & Bever, 1995; Schütze,

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1994). These similarities suggest a potentially substantial relationship between mechanisms of incidental learning and those of natural language acquisition.

We therefore decided to ask more directly whether at least the first stages of language acquisition could be shown to involve all of these characteristics: to be accomplished incidentally, to show age invariance, and to employ statistical computations. Those aspects of language acquired by infants are particularly good candidates for investigations of incidental learning, as infants are unlikely to be engaged in explicit, directed learning. Moreover, the linguistic knowledge acquired during the 1st year is largely the result of distributional analyses of the input, including the vowel space (Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992), consonant categories (Werker & Tees, 1984), phonotactic rules (Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993), phonological regularities (Jusczyk, Cutler, & Redanz, 1993), and frequent biphones (Jusczyk, Luce, & Charles-Luce, 1994) of the native language. These early abilities suggest that infants are adept at performing incidental computations of statistical information about their native language. This, in turn, suggests that probing the incidental nature of language learning may render insights about the role of learning in language acquisition.

The particular aspect of acquisition that we investigated concerned word segmentation. Before children can begin to acquire syntax, they must discover the words of their language, a process complicated by the fact that the speech stream is mostly continuous, without consistent pauses or other acoustic cues marking word boundaries (Cole & Jakimik, 1980). Although adults are faced with this problem whenever they are confronted with a novel word embedded in fluent speech, they can use the surrounding familiar words as markers of where the novel word begins and ends. The prelinguistic infant does not have this luxury, at least not initially. Despite the difficulty of segmenting words from continuous speech, however, experimental evidence indicates that infants can succeed at word segmentation tasks by 8 months of age, well before the onset of word production (Jusczyk & Aslin, 1995).

One proposed solution to the word segmentation problem is that infants may be able to exploit statistical cues to word boundaries (Aslin, Woodward, LaMendola, & Bever, 1996; Brent & Cartwright, 1996; Hayes & Clark, 1970; Saffran, Newport, & Aslin, 1996). Across a language sample, sounds that co-occur within words tend to be more highly correlated with one another than sound pairs spanning word boundaries. We (Saffran et al., 1996) have suggested a computational mechanism for using these contrasts to discover word boundaries. To take a simple example, consider the word sequence *prettybaby*. *Pre* is followed by *ty* with some probability. *Ty,* however, is followed by *ba* rarely, in particular, only when a word ending in *ty* happens to be followed by a word beginning with *ba.* Thus, the transitional probability from one sound to the next will generally be highest when the two sounds follow one another word-internally; transitional probabilities spanning word boundaries will tend to be relatively low. We (Saffran et al., 1996) demonstrated, in an explicit-learning task, that adult subjects were able to use transitional probabilities to learn the multisyllabic words of an artificial language presented as a synthesized speech stream containing no other cues to word boundaries.

In the present study, we asked whether this purely statistical word segmentation task can be accomplished incidentally, and, in addition, whether children might perform comparably to adults. The experiments tested a fairly extreme version of the incidental-learning question, by investigating whether this aspect of early language learning can be achieved while subjects are focused on an entirely unrelated task. Incidental-learning studies typically require the subject to perform some task involving the relevant information, such as memorizing the stimulus strings or predicting the next item in a string. Even studies in which learning occurs solely by observation nonetheless require subjects to attend to some aspect of the relevant stimuli (e.g., Hasher et al., 1987; Reber & Allen, 1978). The present study, however, utilized a cover task in which subjects created computer illustrations, and were told nothing about the language stimuli except that an audiotape that would be playing in the background might affect their artistic creativity. Subjects were not told that the tape consisted of a language, nor that they would be tested in any way during the course of the experiment. Any learning that occurred was thus doubly incidental, in that attention was directed neither to the word segmentation task nor to the acoustic stimuli forming the words. The question of interest was whether word units could be discovered under these conditions, and whether children could approach the performance level of adults on such a complex task.

EXPERIMENT 1

Method

The adult subjects consisted of 12 University of Rochester undergraduates who were recruited from introductory psychology courses and received course credit for their participation. The child subjects consisted of thirteen 6- and 7- year-old children, recruited from a local elementary school. All subjects were monolingual English speakers.

A 21-min audiotape, consisting of 300 tokens of each of six trisyllabic nonsense words (see Table 1) spoken in random order, was created. A speech synthesizer (MacinTalk) was used to generate the speech stream; no pauses or any other acoustic or prosodic cues to word boundaries were present. A sample of the speech stream is *bupadapatubitutibudutabapidabu.* . . . The only cues to word boundaries were the transitional probabilities between syllable pairs, which were higher within words (ranging between .31 and 1.0) than across word boundaries (ranging between .1 and .2).

Six nonword foils were created to test subjects' learning, using syllables from the language in sequences that never occurred during the exposure period, even across word boundaries (see Table 1). In the test, the nonwords were exhaustively paired with the six words, resulting in 36 two-alternative forced-choice trials, presented in pseudorandom order on a second audiotape. (See Saffran et al., 1996, for more detailed information about the stimulus materials.)

Subjects were told that they were participating in an experiment investigating the influence of auditory stimuli on creativity, and that they had approximately 20 min to work on an illustration using Kid Pix 2©, a coloring program designed for children, while a tape was playing in the background. After 21 min of coloring (the duration of the tape), subjects were informed that they would

Table 1. *Words and nonword foils used in Experiments 1 and 2*

Words	Nonwords
babupu	batipa
bupada	bidata
dutaba	dupitu
patubi	pubati
pidabu	tipabu
tutibu	tapuba

be tested on their memory of sounds from the tape that had been playing while they were drawing. The experimenter asked subjects to listen to the two sets of sounds they would hear on each trial, and to respond "one" or "two" to indicate which set of sounds seemed more like the tape they had heard. Guessing was encouraged. Subjects were not told that the sounds were actually words from a nonsense language. After four practice trials using word-nonword pairs from English to ensure that subjects understood the response procedure, the 36 test trials were presented.

Results and Discussion

Figure 1 presents the scores of the adult and child subjects on this task. The mean score for the adults was 21.1 out of a possible 36 (58.6%), where chance equals 18. A single-sample t test (two-tailed) showed that performance was significantly better than chance, $t(11) = 2.38, p < .05$. The mean score for the children was 21.3 (59.2%), which was also significantly better than chance, $t(12) = 3.67, p < .01$. The difference between adults' and children's performance was not significant, $t(23) > 1$, n.s.

Although this study clearly indicates that learning may proceed in the absence of directed attention to the input, subjects' performance was moderate (see Fig. 1). Thus, in Experiment 2, we doubled the duration of exposure to the speech stream to obtain improved learning. We also wished to see whether the age invariance observed in Experiment 1 would be maintained over any improvements in performance.

EXPERIMENT 2

Method

Twelve adult college students from the University of Rochester campus were recruited as subjects, and paid $10 for their participation. Eleven 6- and 7-year-old children were recruited from summer camps held at the University of Rochester.

Materials were the same as in the previous experiment, as was the procedure, except that subjects participated in two sessions of the experiment on subsequent days. In the first session, subjects colored while listening to the 21-min tape, but were not tested (and therefore were also not informed about the significance of the language stimuli). In the second session, subjects colored and listened to the 21-min tape a second time. They received the same test as in Experiment 1 at the end of the second session.

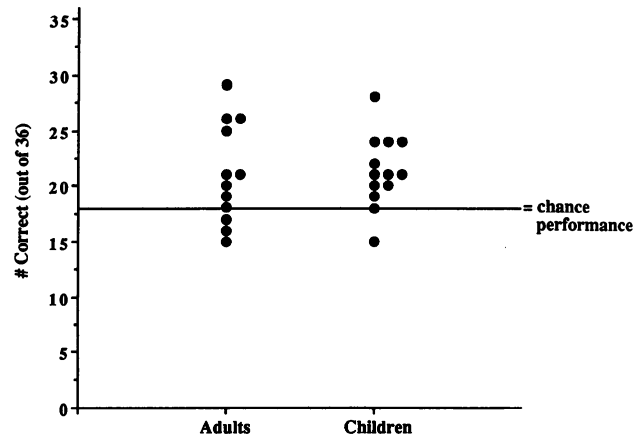

Fig. 1. Scores for adult and child subjects in Experiment 1.

Results and Discussion

Figure 2 presents the scores of the adult and child subjects on this task. The adults obtained a mean score of 26.3 (73.1%), which was substantially and significantly better than chance, $t(11) = 6.33, p < .01$. The children obtained a mean score of 24.6 (68.3%), which was also substantially and significantly better than chance, $t(10) = 5.56, p < .01$. There was no significant difference between the scores of the adults and children, $t(21) > 1$, n.s. An analysis of variance indicated that performance in Experiment 2, when exposure duration was doubled, improved significantly compared with performance in Experiment 1, $F(1, 46) = 12.5, p < .01$. There was no main effect of age, $F(1, 46) = 0.162$, n.s., and no interaction between length of exposure and age, $F(1, 46) = 0.94$, n.s., indicating that longer exposure was equally beneficial for the two age groups.

GENERAL DISCUSSION

Despite the brevity of the exposure and the complexity of the stimuli in this task, subjects learned about the words of the artifi-

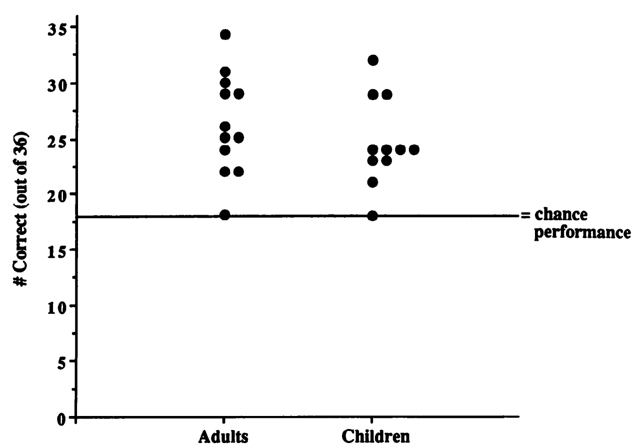

Fig. 2. Scores for adult and child subjects in Experiment 2.

cial language—in the absence of any directions to listen to (let alone learn about) the speech stream. The fact that children, in particular, learned under these conditions suggests that incidental learning is a robust phenomenon that may play a role in natural language acquisition. These results also suggest that the computation of transitional probabilities can proceed incidentally, and therefore might underlie aspects of both natural language acquisition and learning in other domains.

Of course, the linguistic input presented a more concentrated learning exposure than would be available to a learner in a more natural learning environment. At the same time, the input was quite impoverished, containing neither utterance boundaries nor the acoustic and prosodic cues that are probabilistically correlated with word boundaries in some languages (see Saffran et al., 1996, for further discussion of the availability and limitations of nonstatistical cues to word boundaries). Rather than including all the cues necessary for a model of the natural acquisition of word boundaries, the experimental situation specifically targeted the incidental learning of statistical information.

Unlike most researchers employing incidental paradigms, we were not trying to assess whether learning can occur in the absence of conscious awareness.[1] In fact, our subjects ranged greatly on that dimension: Some subjects reported that they were aware of learning during the exposure period, whereas others actively tuned out the speech stream and were unaware of learning anything at all.[2] Rather, our intent was to observe the process of language learning in a situation more characteristic of children's language acquisition than is usually found in laboratory studies of language learning. The performance of our subjects suggests that passive exposure is sufficient for at least some aspects of language learning.

The present study also provided a learning situation that is perhaps even more challenging than the child's actual language environment. In natural language acquisition, the child is presumably attending to linguistic input in order to understand and communicate, if not intentionally to learn. In the present study, however, the linguistic input was in the background and not part of the primary task. Nevertheless, the relevant information was acquired, suggesting that the induction of at least some types of structure from linguistic (and perhaps nonlinguistic) stimuli is a process so natural that it can proceed in the absence of any instructions or external motivation to learn.

One particularly interesting aspect of these results is that the children performed as well as the adults in both experiments. This finding suggests that the computation of the kinds of low-level contingencies found in some aspects of linguistic input is achieved with equal ease by learners who differ vastly on other dimensions of cognitive ability. This absence of age differences is in line with the literature on age of learning in natural language acquisition. In that literature, basic and early-acquired aspects of the language are learned equally well by younger and older learners. For example, basic word order is acquired equivalently by both child and adult learners (e.g., Johnson & Newport, 1989; Newport, 1990). Critical-period effects (i.e., superiority of child learners over adults) emerge later in learning, particularly for more complex syntactic and morphological structures (e.g., Johnson & Newport, 1989; Krashen et al., 1982; Newport, 1990; Slavoff & Johnson, 1995). Further research is needed to investigate whether the superiority of child learners over adults in later stages of natural language acquisition will also appear in more complex statistical learning tasks in the laboratory, or whether these stages involve a different set of learning mechanisms that are not statistical in nature.

In conclusion, we would like to suggest that two distinct lines of research, investigating incidental learning on the one hand and natural language acquisition on the other, would each be well served by a consideration of the theoretical and empirical concerns of the other (see N.C. Ellis, 1994, for recent work forging connections between these two literatures). The phenomena observed in children's language acquisition suggest a number of incidental-learning mechanisms pertinent to researchers in the field of learning. Similarly, researchers studying children's language acquisition would benefit from considering at least some of the mechanisms that have been uncovered by learning research. Language acquisition theorists have had a tendency to dismiss learning as a minor or theoretically uninteresting component of language acquisition, focusing instead on the innate knowledge required to solve the notoriously difficult learning problems encountered in acquiring a natural language.

The present approach takes learning seriously as a potential critical aspect of language acquisition. Our results suggest that learners are remarkably adept at absorbing surprisingly detailed and purely formal linguistic information from language input, without any external impetus to do so. These results also raise the possibility, to be investigated in future research, that learners show these abilities for only certain types of statistical information, or that some implicit statistical computations are favored over others. If so, then at least part of the innate contribution to language acquisition may be how humans are constrained to learn structured systems like language, rather than direct innate knowledge about the structure of the systems to be learned. Such learning abilities are a critical aspect of the child's genetic endowment, and as such may also be a crucial component of the human language-learning instinct.

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1. Whether or not this learning is accessible to consciousness is orthogonal to the question of whether incidental learning may play a role in language acquisition. It is clear that some aspects of linguistic competence are in fact available to conscious introspection (e.g., that *cat* is a word), whereas other aspects of competence may not be (e.g., some syntactic generalizations). Moreover, developmental data suggest that aspects of language which are initially encoded implicitly may become progressively more explicit and accessible to verbal report (e.g., Karmiloff-Smith, 1992).

2. These differences in reported awareness did not correlate with performance.

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