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Babies Catch a Break: 7- to 9-Month-Olds Track Statistical Probabilities in Continuous Dynamic Events

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Events are dynamic and continuous, with no pauses to mark boundaries between individual actions. In stark contrast, language describes categories of actions and events that have discrete beginnings and ends, such as *The boy climbed the ladder* and *The man slid down the pole*. Language learning thus requires that children segment continuous events into units that will be labeled by verbs like *climb* or *slide*.

Research indicates that infants are sensitive to boundaries in continuous events (Hespos, Grossman, & Saylor, 2010; Saylor, Baldwin, Baird, & LaBounty, 2007). How they divide the flow of information into discrete actions, however, remains unclear. Some researchers suggest that infants use speech-action synchrony, such that points of convergence act like wedges to carve individual action units (Brand & Tapscott, 2007). Others hold that familiar routines anchor the segmentation of events (Hespos et al., 2010). Still others argue that attention to actors' intentionality offers functional units that structure the world (Baldwin, Baird, Saylor, & Clark, 2001). A more general mechanism that could work in tandem with each of these strategies is statistical learning. Infants' ability to track transitional probabilities in continuous auditory speech is well documented (Aslin, Saffran, & Newport, 1998; Saffran, Aslin, & Newport, 1996). After hearing an artificial language, 8-month-olds differentiate its wordlike units from part-words, even when the frequency of exposure to test items is controlled (Aslin et al., 1998). Statistical learning also extends to the visual domain. Adults can track transitional probabilities in continuous, dynamic events (Baldwin, Andersson, Saffran, & Meyer, 2008), but studies of infants' visual statistical learning have investigated their performance with static pictures only (Fiser & Aslin, 2002; Kirkham, Slemmer, & Johnson, 2002). Perhaps statistical learning is a tool with which infants find bounded actions in events.

In the study reported here, we examined whether infants use statistical learning to parse continuous, dynamic events. Our approach paralleled that of research showing that infants utilize transitional probabilities in a corpus of natural speech (Pelucchi, Hay, & Saffran, 2009) and use statistics to distinguish words from part-words (Aslin et al., 1998). Thus, we familiarized infants to a corpus of dynamic, continuous events and tested their ability to differentiate units from part-units.

Method

Twenty monolingual infants (10 female, 10 male) between the ages of 7 and 9 months (M = 8.63, SD = 1.00, range = 7.03–9.90) were familiarized to a 4-min videotaped corpus of hand motions. Twelve distinct motions were performed by a male actor (whose face was digitally blurred) at a constant speed of one hand motion every 500 ms. Within the video of continuous hand motions, actions were grouped into triads such that the three hand motions in each triad always appeared in the same order as a unit. Units were arranged according to the frequency-controlled model (Aslin et al., 1998). During familiarization, an audio attention getter played when infants looked away from the video for 1 s and continued to play without interrupting the video until infants resumed looking at the screen.

At test, infants saw three blocks of test trials, each consisting of four trials presented in varying order. Two trials in each test block presented statistically intact units, and two presented part-units (i.e., the last hand motion of one unit plus the first two hand motions of another unit). Critically, all units and part-units used in the test trials appeared with equal frequency during familiarization; the only difference between these units and part-units was their transitional probabilities. Each pair of successive hand motions within a unit had a transitional probability of 1.0; within a part-unit, the first and second hand motions had a transitional probability of .5 (across the unit boundary), and the second and third hand motions had a transitional probability of 1.0 (Fig. 1a). Each test trial was preceded

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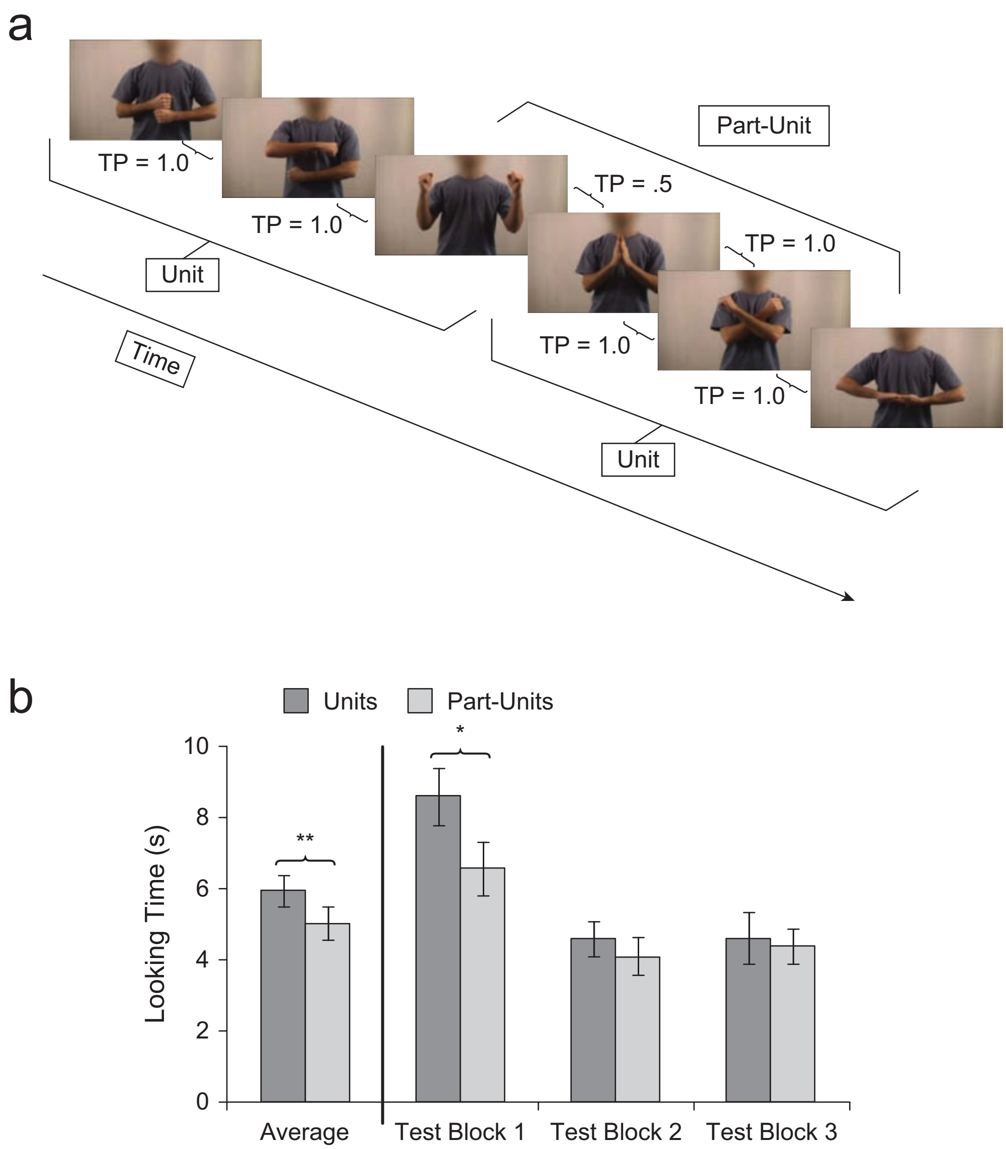

Fig. 1. Examples of units and part-units from Corpus A and infants' looking time to units and part-units at test. Each unit comprised three hand motions that always appeared together in the same order (a). Part-units combined the third hand motion from one triad with the first two hand motions from a different triad. Each pair of successive hand motions within a unit had a transitional probability (TP) of 1.0; the transitional probabilities for the hand motions within a part-unit were .5 for the first pair and 1.0 for the second pair. The graph (b) shows the overall average looking time to units and part-units, as well as looking time to units and part-units as a function of test block. Error bars represent standard errors of the mean. Asterisks indicate significant differences (* $p < .05$; ** $p < .01$).

by an auditory and visual attention getter. During each test trial, the test unit or part-unit was presented for 1,500 ms (one presentation of the three-motion unit or part-unit), and then the screen faded to gray for 500 ms (the interstimulus interval); this sequence was repeated until the infant looked away for 1 s or for a maximum duration of 15 s. A final, recovery trial that showed a laughing baby was included so that we could ensure that the participants were not fatigued. All the infants looked longer to this recovery trial than to each test trial.

We created two corpora and manipulated the corpus used in familiarization as a between-subjects variable. Test sequences were identical for the two corpora, but the sequences that were units for Corpus A were part-units for Corpus B and vice versa. This manipulation ensured that differential responses at test could be attributed to statistical learning rather than to specific hand-motion combinations.

Results

Infants' looking times to units and part-units were averaged across all test trials. To examine whether infants showed differential patterns of looking to units and part-units at test, we conducted a 2 (corpus: A vs. B) × 2 (trial type: units vs. part-units) repeated measures analysis of variance. Results revealed a main effect of trial type, $F(1, 18) = 7.76$, $p < .05$, $\eta_p^2 = .30$, but no main effect of corpus and no interaction. A paired-samples *t* test confirmed that infants (15 out of 20) looked longer toward statistically intact units than toward part-units, $t(19) = 2.85$, $p < .01$. Planned contrasts suggested that the main effect of trial type was driven by looking time in the first block of test trials, in which infants looked longer toward the units than toward the part-units, $t(19) = 2.39$, $p < .05$ (Fig. 1b).

Discussion

This study provides evidence that infants use statistical learning to detect units within continuous, dynamic events that approximate events in the world.[1] The ability to segment these units is critical not only for interpreting meaning in the flux and flow of events, but also for language learning. As Sharon and Wynn (1998) suggested, "For language to be comprehensible, two people must have the same bounded pattern of motion in mind when they refer to a 'jump,' a 'hug,' or a 'hit'" (p. 357). Together with an appreciation of speech-action synchrony, familiarity, and actor intent, statistical learning begins to explain how infants carve a world that continuously unfolds across space and time into units, like *climbing* and *sliding*.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Note

1. An alternate interpretation is that infants extracted static snapshots from the dynamic events to compute transitional probabilities. This *snapshot* explanation is not parsimonious, however, because it requires that infants calculated transitional probabilities between all successive frames of the 4-min video. Transitional probabilities between successive frames within a unit were 1.0; transitional probabilities were lower only for pairs consisting of the frame ending one unit and the frame beginning the next unit. The snapshot interpretation increases the number of statistical calculations required and places a high burden on detecting the brief decreases in transitional probability that distinguished unit boundaries. Thus, we interpret our findings as evidence that the infants computed statistics in dynamic events.

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